The Toolchain of Energy Agents for Electrical Distribution Grids

(and any other energy system configuration)

Agent Summer School - 15.07.2022

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Outline

- Introduction: The AWB - “Smart Grid” example project
- Selected Challenges
- Energy Agents
- Energy System Models as base for the Energy Agents reasoning
- Remarks on MABS (Multi-Agent based simulations)
- Conclusion

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Live presentation:
The AWB - “Smart Grid” example project

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Selected Challenges in the currently ongoing Transition of the Energy Sector

Transition and increasing Digitization of the Energy Sector

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Selected general Challenges (for sure uncomplete)

- Climate Changes
- Carbon Dioxide Reduction
- Increased Volatility in Production (e.g., through PV & Wind)
- Sector Coupling (combine electrical, heating, gas and other)
- Organizational Affiliation
- Locale und global standards
- Markets + Regulation
- …

Source: https://digilux.blog/2018/02/05/smart-grid/

Requirements for decentral software (unsorted)

- Data-Recording
- Monitoring + Machine Learning
- Communicate information
- Control energy systems
- ensure to keep control objectives
- …

We‘re using the notion of „Energy Agents“
as an equivalent for these decentral software components

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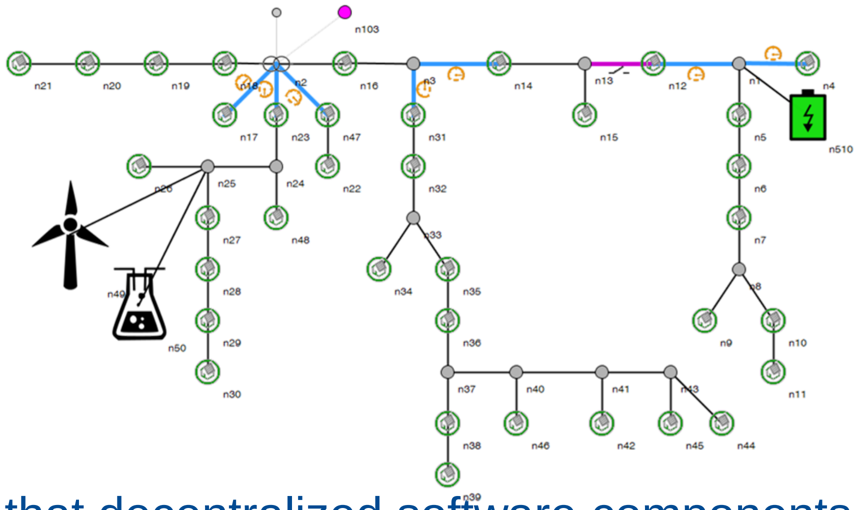
Energy Agents

Properties of Energy-Agents

- **Autonomy:** Agents are autonomous control processes (also applies for simualtions!)
- **Able to communicate:** Agents can exchange messages
- **Environment**: Agents are embedded in an environment
- **Deliberative**: Agents are able to understand the energy systems assigned for controlling and planning

General Modelling Approach

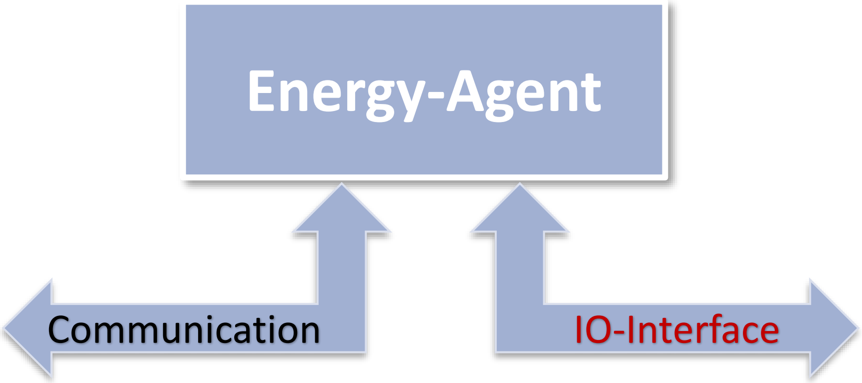
- Each active component is represented by an Energy Agent (e.g., households with PV, batteries, CHP, …)
- Especially for **Simulations**, the ”Environment“ is represented by a suitable environment model (e.g., for our distribution grid) needs to be managed by a central unit (in our case an agent, too)



Why using the notion “Energy Agent”?

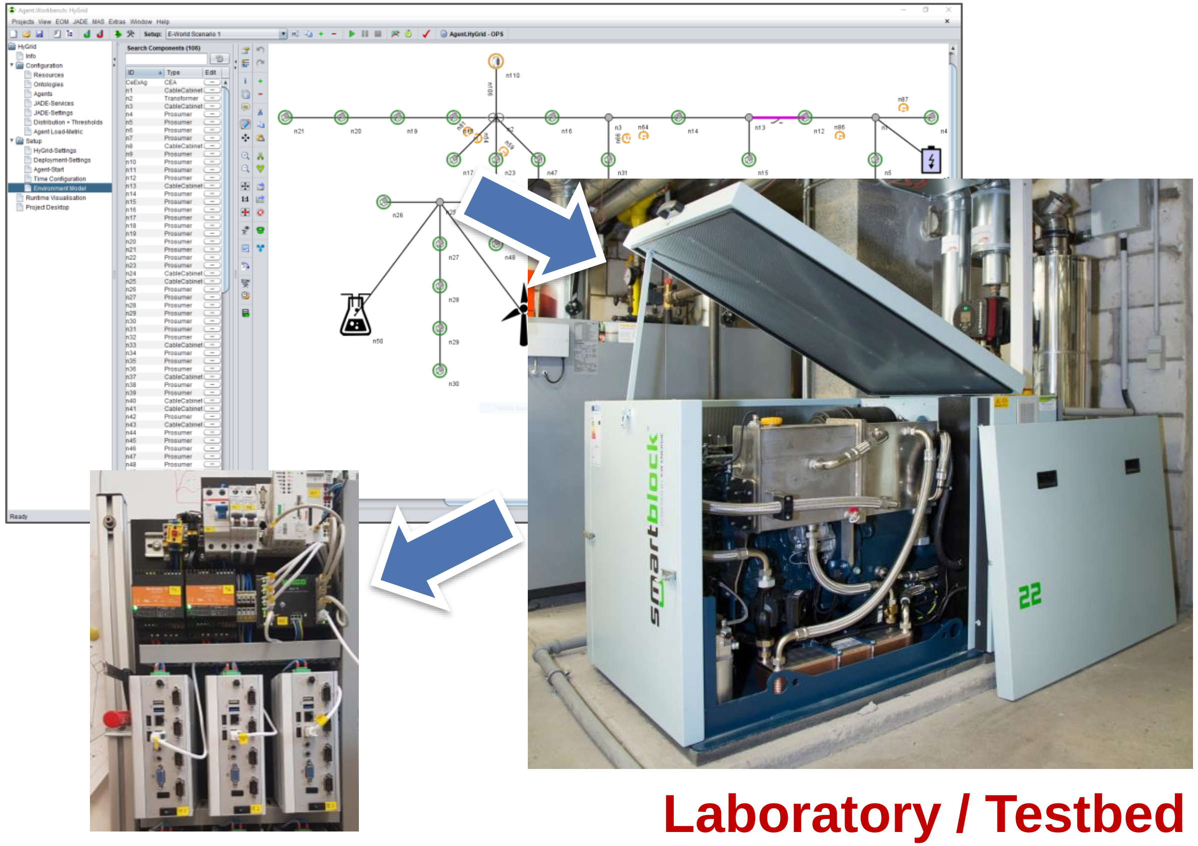
- Because of their focus on the energy sector and our understanding that decentralized software components in that application needs to have similar capabilities (e.g. using the same language), we force the notion as a demand for Standards!

Seamless usage of Energy-Agents: Our Development Process



- Die actual interface to technical systems (our so-called IO-Interface) changes with the use case shown on the right
- The core of Energy Agents remains identically equals, which means internal process as well as inter-agent communication do not change in our development process till the real on-site usage

Simulation



Real Usage

Laboratory / Testbed

Definition

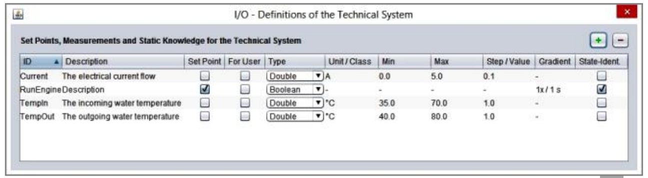
An Energy Agent is a specialized autonomous
software system that represents and economically manages
the capacitive abilities of the energy consumption,
production, conversion and storing processes
for one or several technical systems
and that is embedded and thus part of one or more
domain specific energy-networks,
capable to communicate therein
and with external stakeholders

Integration Level of Energy Agents

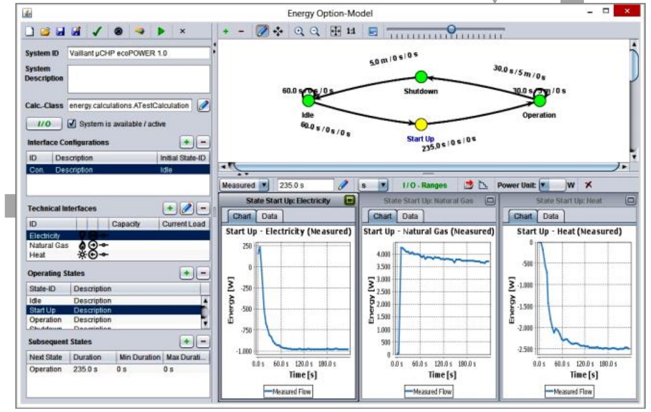
Integration Level		Overall Control	Description
IL0		Central	Initial situation: old state of the art from the 80s (e. g. Bakelite ferrite electric meters and newer meters without information exchange)
IL1	Energy Agent !	Central	Current meter systems: enables information transfer of energy usage, but requires a central data analysis
IL2		Central	Advanced meter systems with predictions: enables information transfer of energy usage with locally aggregated data
IL3		Central & Local	Advanced local controller: Can act on the underlying local system and react autonomously to external signals (e. g. price signals for local optimization)
IL4		Central, Distributed & Local	Advanced local area controller: restricted, but independent local systems that can dynamically build coalitions in order to keep track of optimization goals (e.g. intelligent local power transformers, responsible for one network segment)
IL5		Distributed & Local	Fully distributed control of energy production, distribution and supply

Energy System Models as base for the Energy Agents reasoning

The Energy Option Model - Live Demo

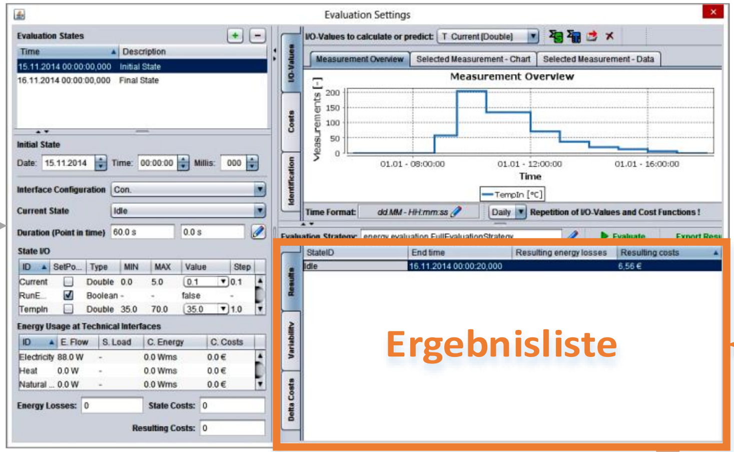


System Variables: set points, user preferences , measurements, static data models etc.



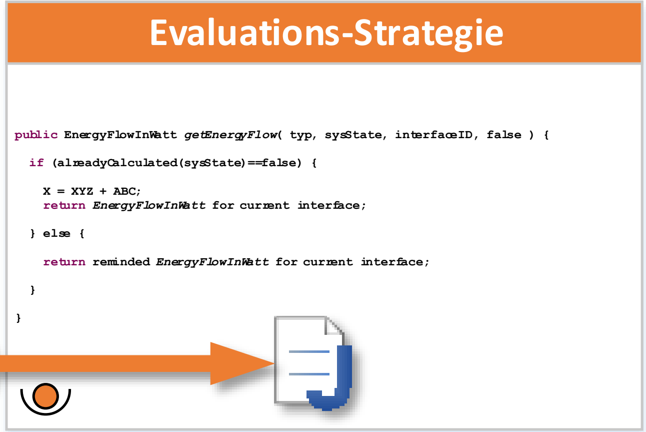
Base Model: interface configuration, network connections, energy carrier, operating states, temporal energy flows

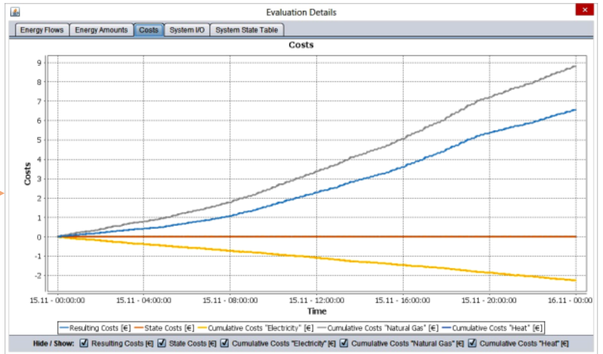
OptionModelCalculation



Evaluation Setup: predictions, cost model, state identification, initial and final system state

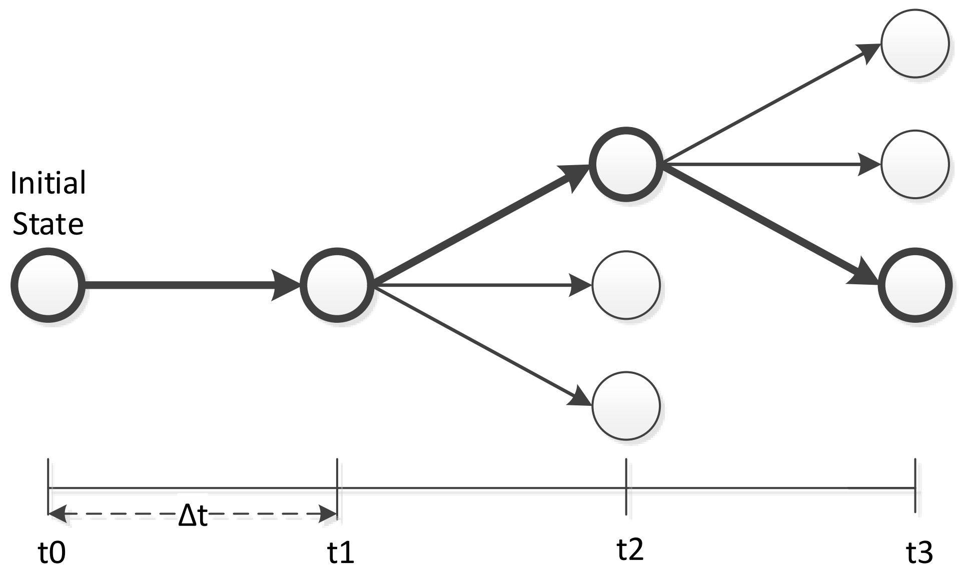
EvaluationCalculation





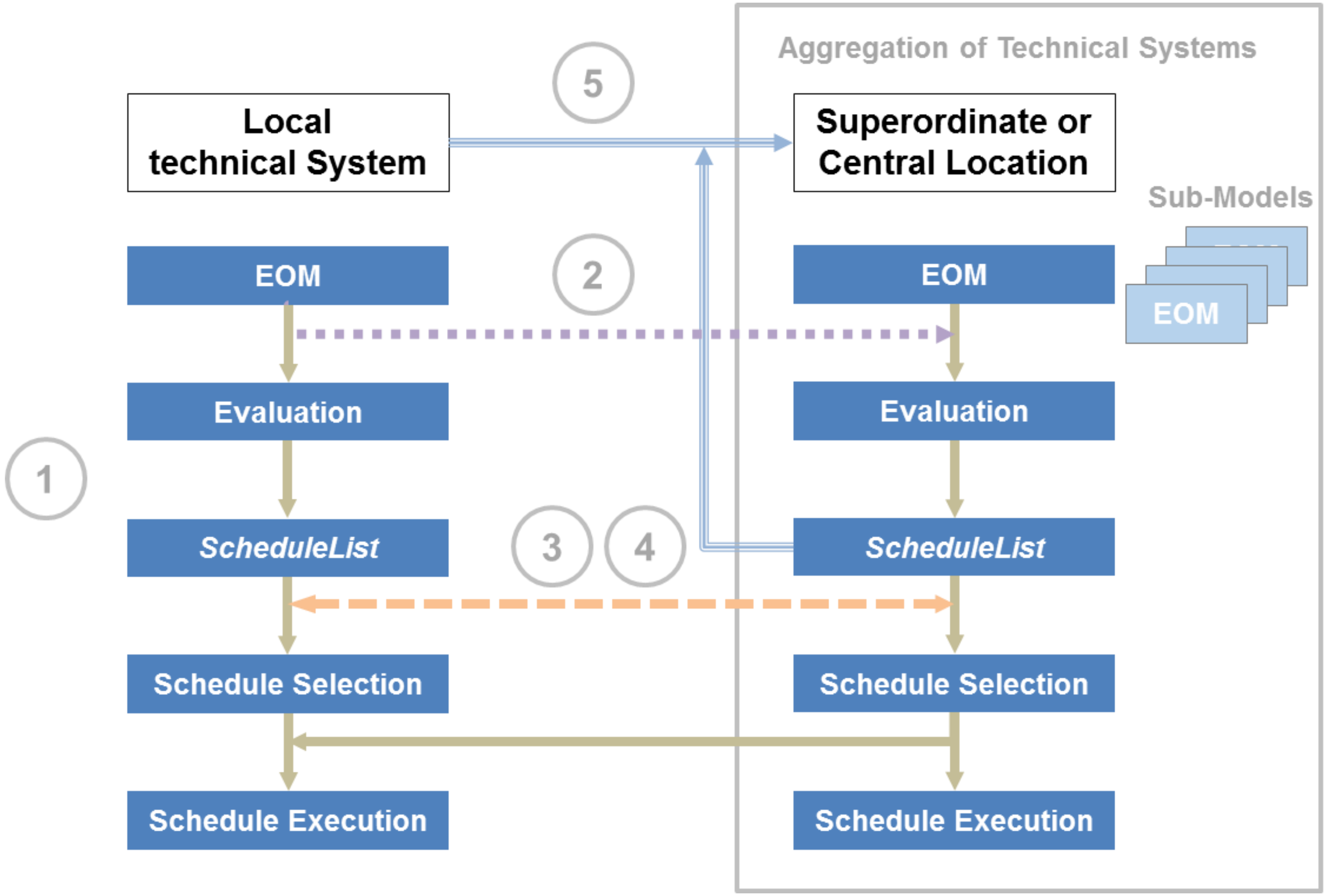
State History and Results: Energy flows, Energy amounts, losses, costs, I/O-History

Unified Decision Making Process of the EOM



Consecutive in time and dependent on each other

Possible Usage of the modular EOM approach



1. Single local system
2. Provide a system model to a central aggregator
3. Central aggregator sends result schedule to local system for execution
4. Local system sends result schedule to central aggregator
5. Decentral optimization (e.g. by using Round Robin communication)

Remarks on MABS
(Multi-Agent based simulations)

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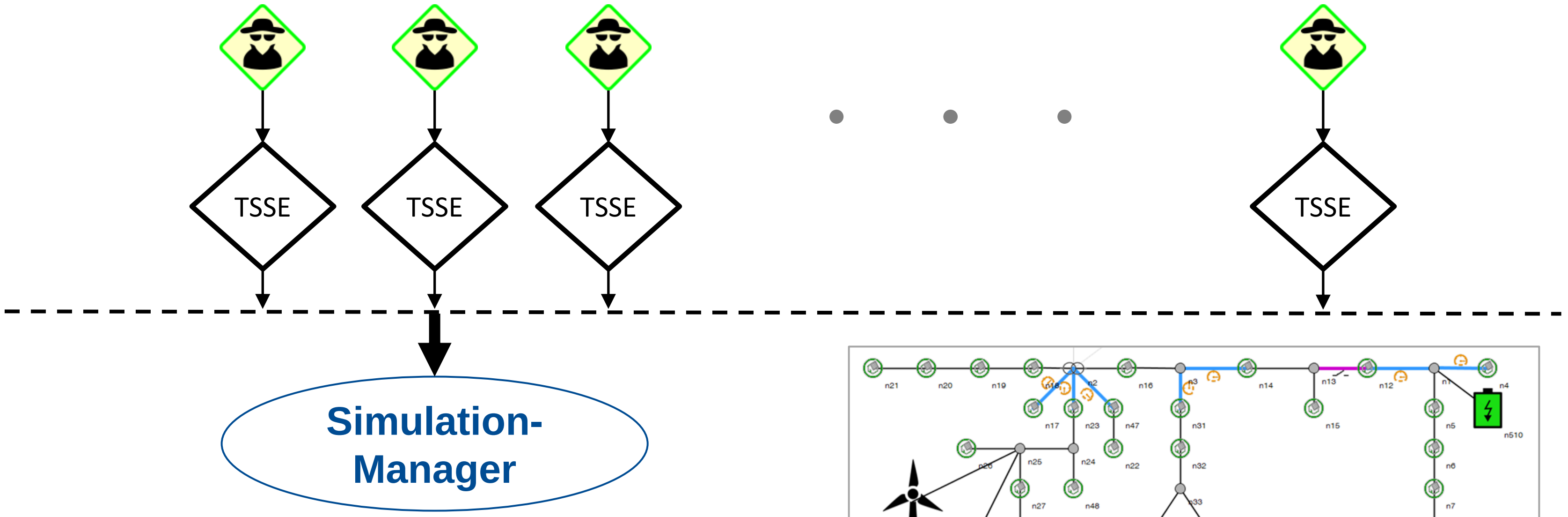
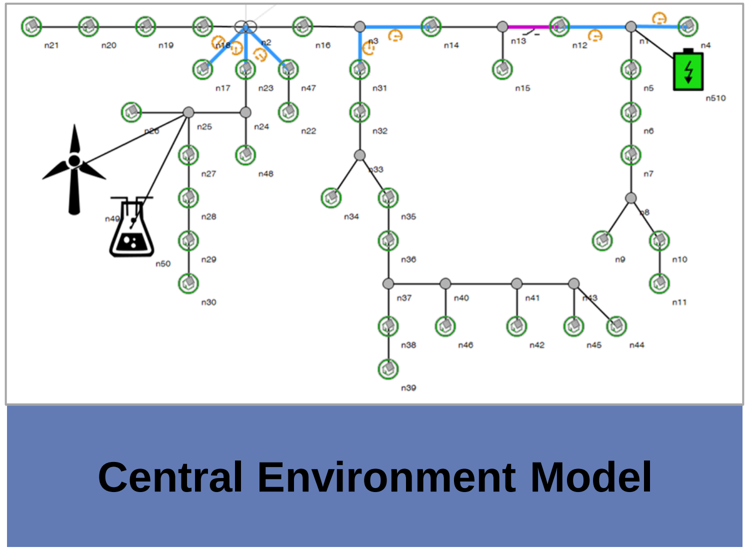
Generative Simulation Principle



„Environment Model Manager “

- Coordinate simulation schedule
- Receives system states (TSSE‘s)
- Execute network calculations
- Updates the Visualization
- Distributes Information by using a simulation blackboard



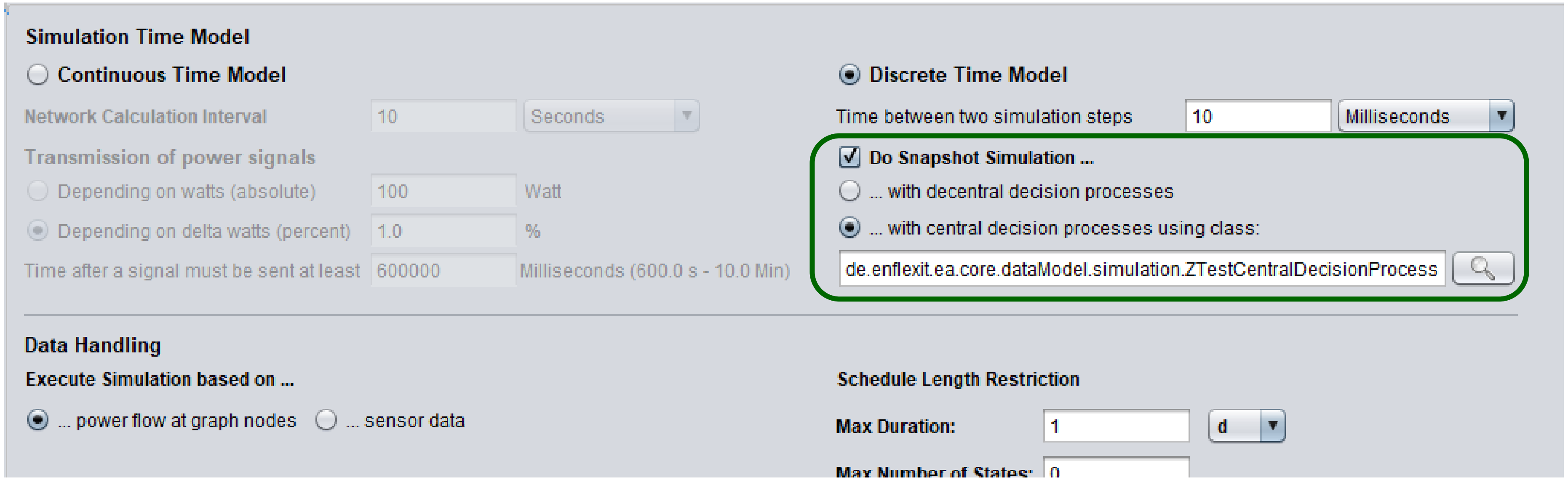
Properties

- The overall system state results from form the single system states involved in a scenario - the central environment model will be generated
- Simulated System dynamics occurs that causes from decentral decision making
- This corresponds to the natural behavior of real systems (and networks)

Possibilities to simulate with Energy Agents

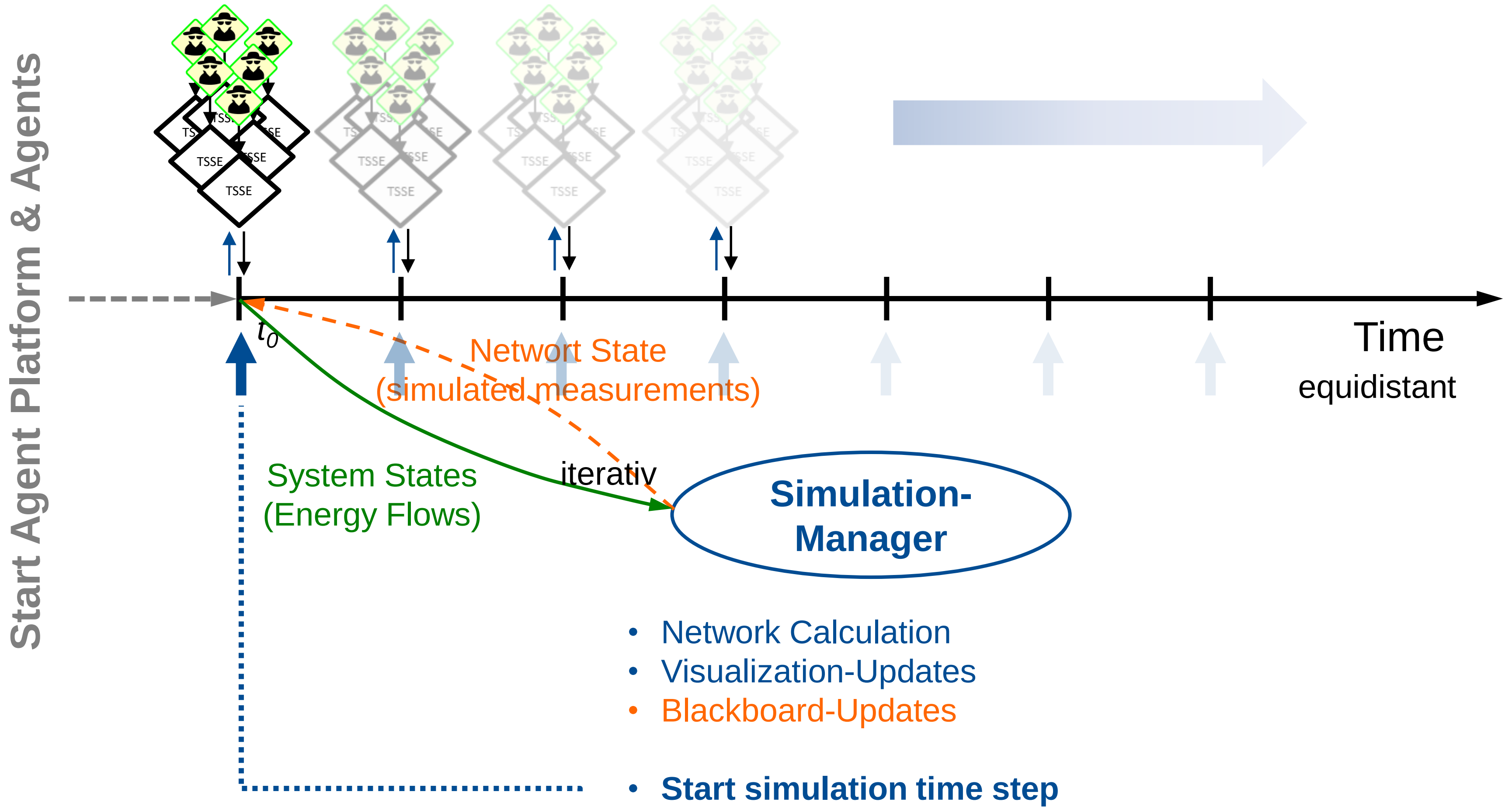
for Real-Time scenarios
(simulation time= real time)

discrete simulations: for longer time ranges
(for any equidistant time step)



Sensors are the source for
network condition determination!

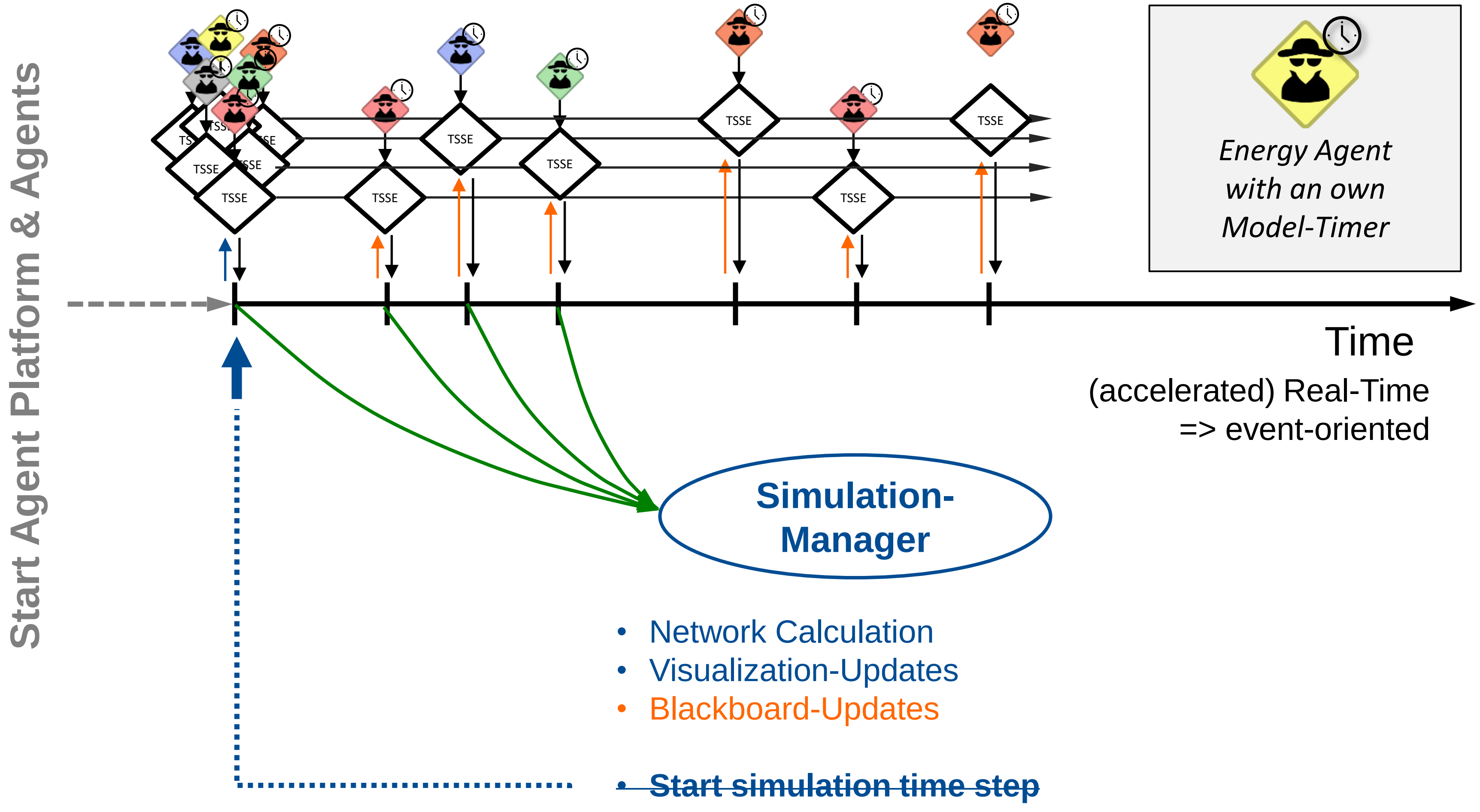
Simulations-Scheduling (discrete)



- Network Calculation
- Visualization-Updates
- Blackboard-Updates

- **Start simulation time step**

Simulations-Scheduling (kontinuierlich)



Conclusion

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- The energy sector is currently undergoing a **fundamental process of change** at all levels (technology, market, regulation) and will continue to do so in the future (**Energy Transition**).
- Under that framework conditions, the cross-cutting issue of **digitization of the energy industry** must aim to automate the control of energy systems and their components as much as possible.
- **Comparability** and **transparency** are, in our view, key factors for the success of this digitization.
- The **complexity** of the software systems to be implemented is high and will continue to increase as requirements continue to grow.
- We therefore assume that the **standardization of decentralized software components that communicate with each other** will play a key role in the realization of these software systems.

=> **Energy Agents** (as distributed, autonomous and intelligent software systems) form our solution approach for such components

Thanks ! - Questions?

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