Swarm Grids for a decentralized power grid control

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and Ingo Stadler

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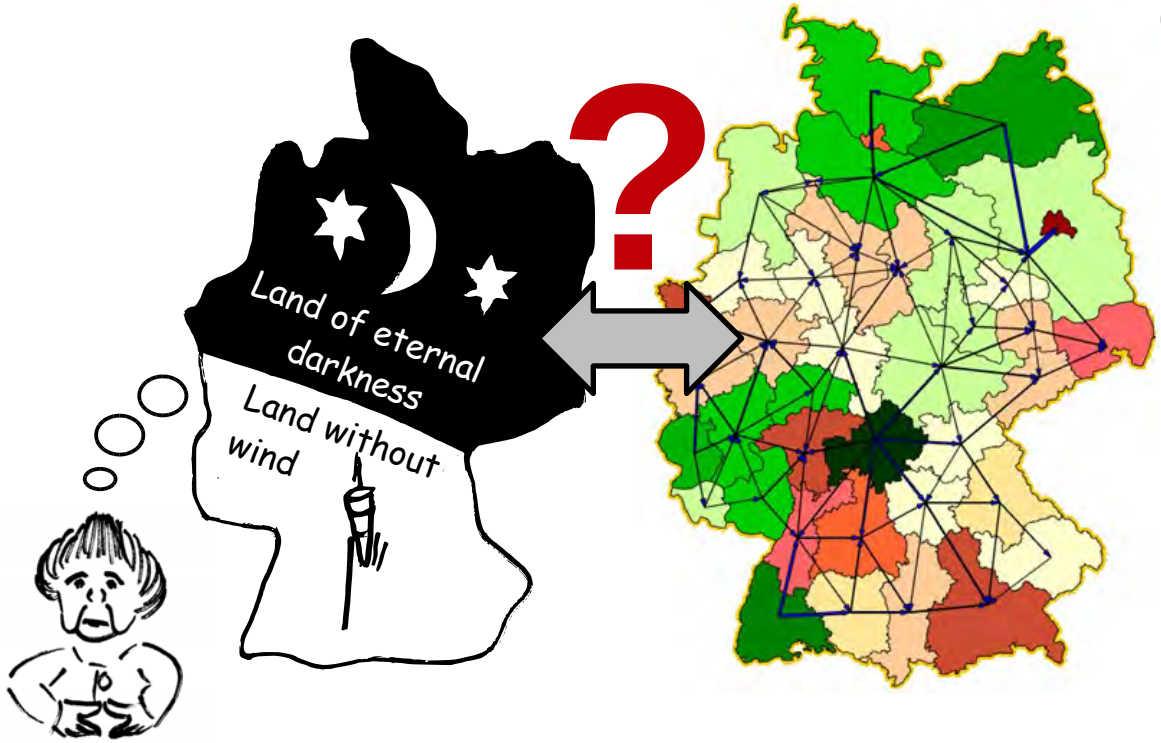
Future power grid structure



Challenges

- Decentralisation
  - Generation
  - Consumption
- Complexity
  - Number of generators
  - New types of consumption

Demands

- Modularity
- Versatility
- Resilience
- Simplicity

Not only power lines,
but management
of a complex power distribution

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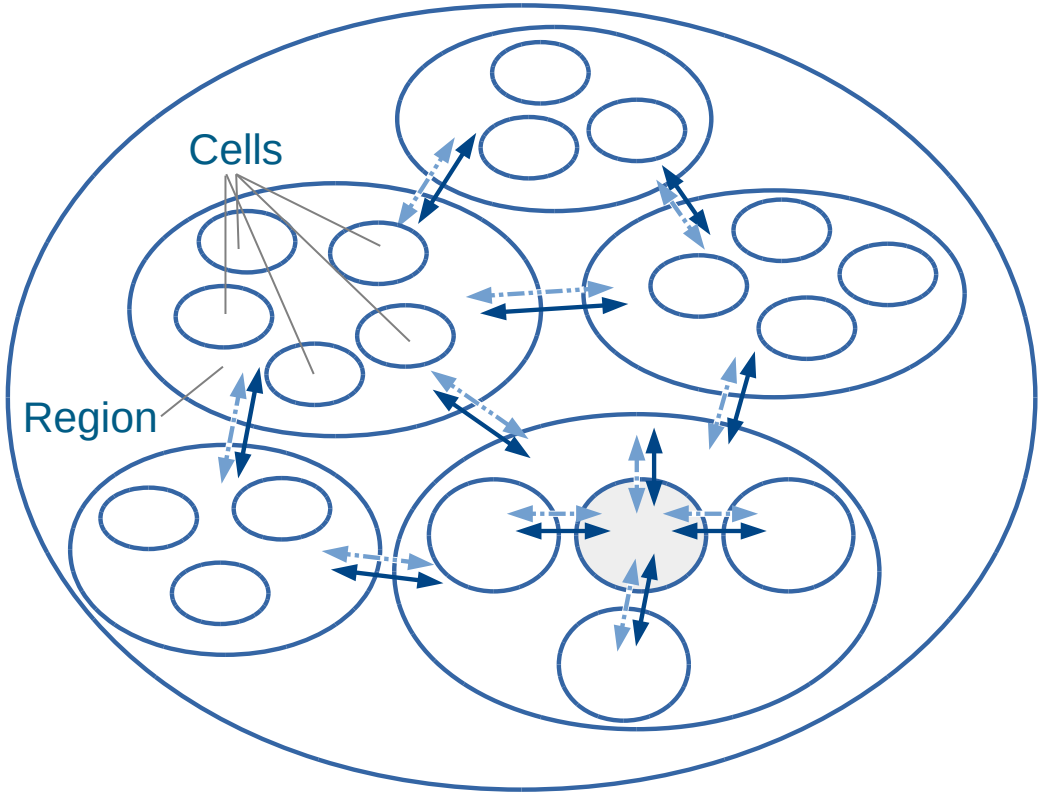
Sketch and Graphic:
Eberhard Waffenschmidt

Cellular power grid



- Decentralized

Organisation of the grid structure:

  - Decentral
  - Regional

- Complexity

  - Divide tasks
  - Independently, cooperating units
  - Hierarchy

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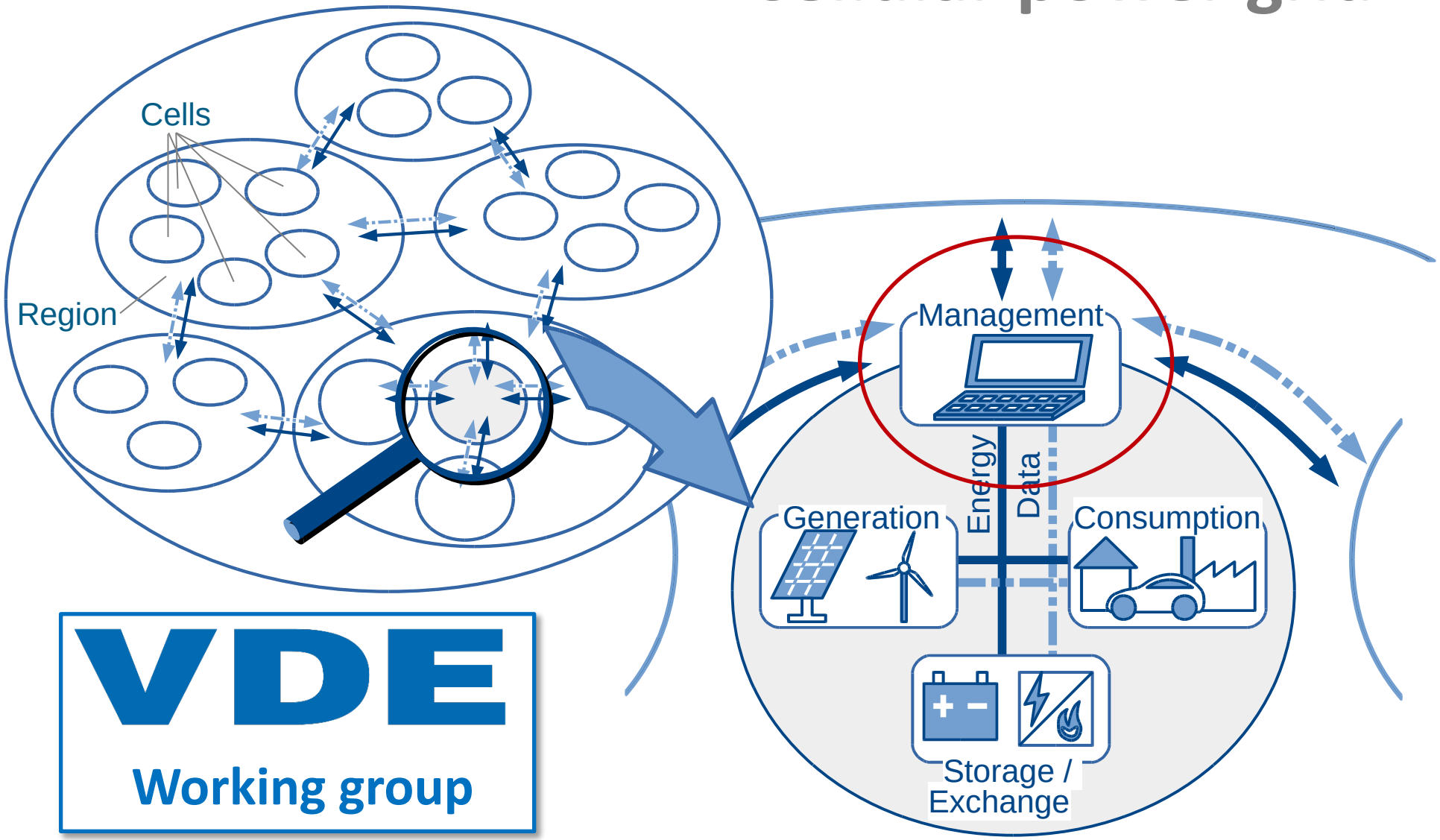
Graphic: E. Waffenschmidt for working group „Energieversorgung 4.0“ der ETG im VDE

Cellular power grid



VDE
Working group

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Graphic: E. Waffenschmidt
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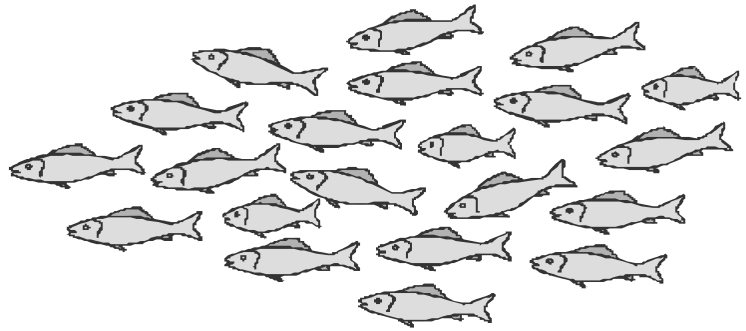
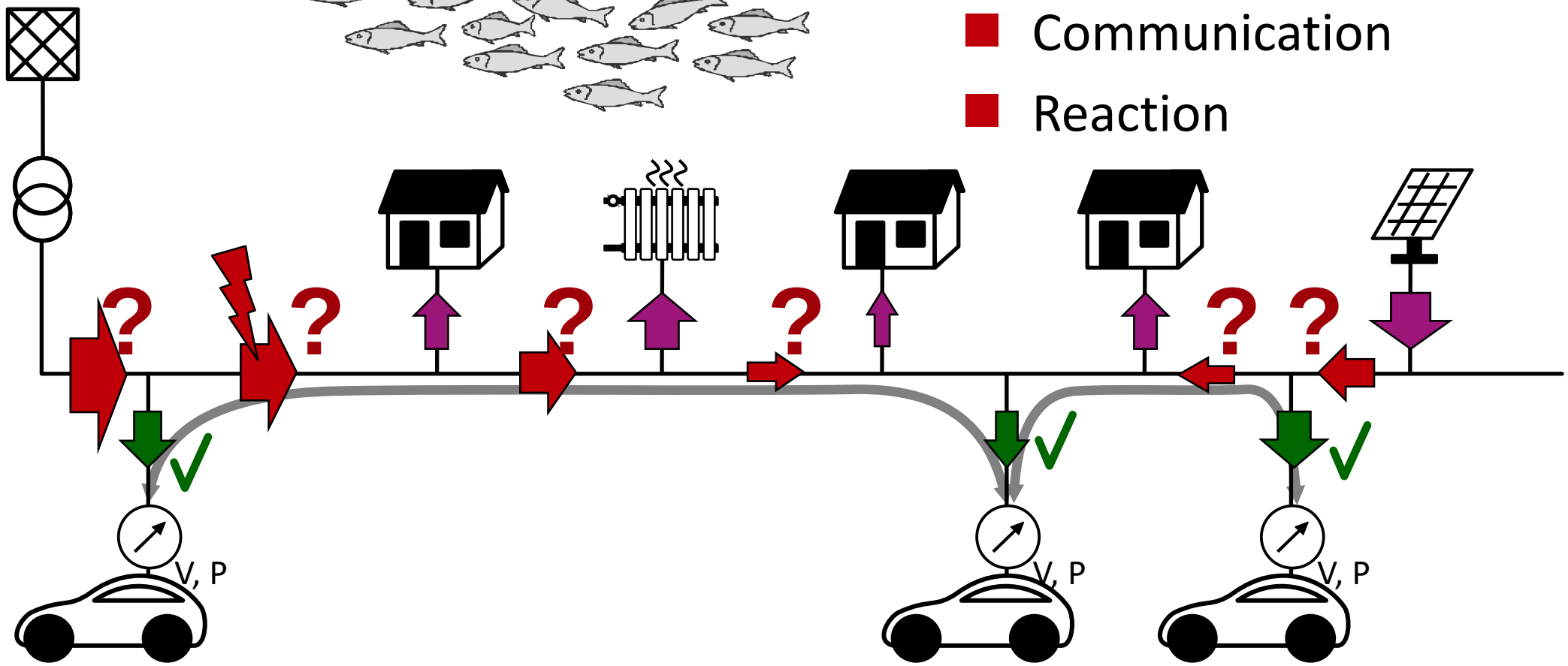
Decentralized grid control with swarm principle.

Mutual aim by

- Detection
- Communication
- Reaction





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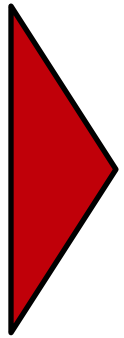
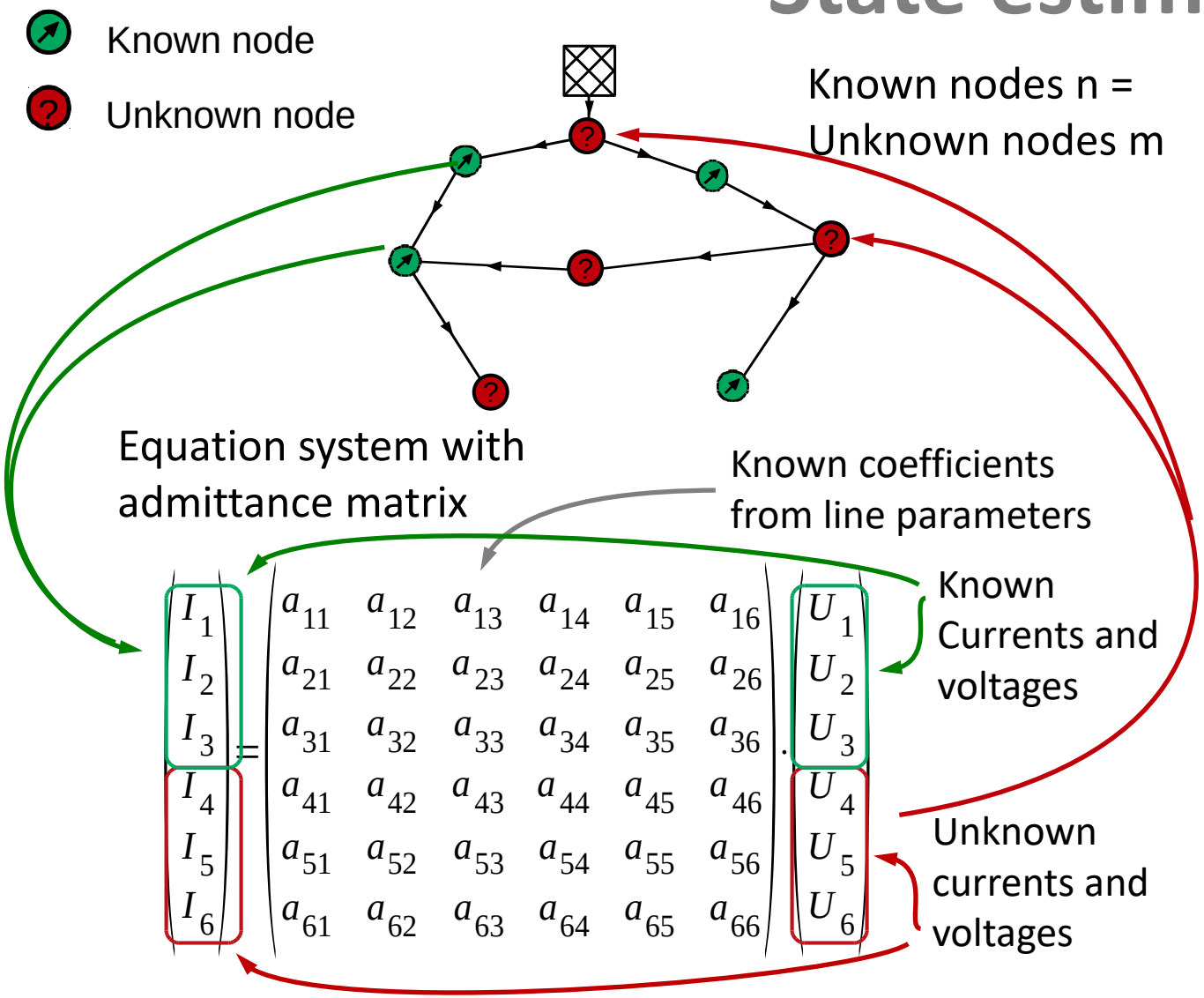
Concept by
Ingo Stadler and
Eberhard Waffenschmidt

Detection:
Grid state estimation



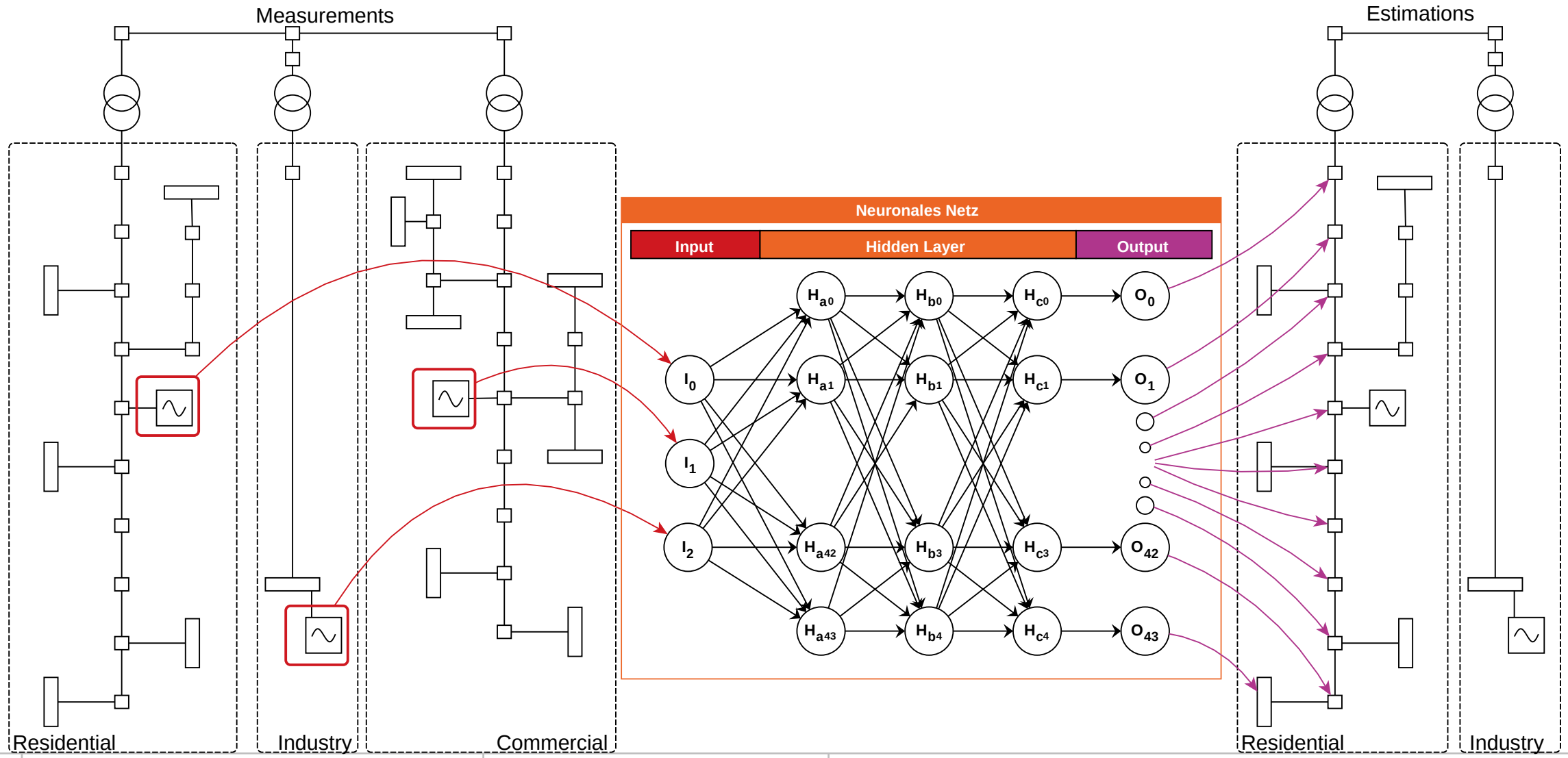
State estimation



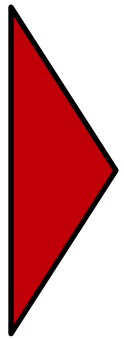
Node potential method

- For more than 2 nodes
- Determines currents from voltages
- Re-arrangement of equation system:
- **Currents and voltages at un-measured nodes**

Power grid state estimation with neural networks



Communication



Communication requirements

- Operational data frame
  - Within few seconds
  - Reliable
  - Peer-to-peer

- Initialisation data frame:
  - Not time critical
  - Size not critical

Message content and length:

Item	*Bytes*
Phase voltages	6
Phase currents	6
Power factors	6
Voltage phasors	6
Required energy	2
Required ending time	2
Station ID	2
Status	1
Check sum	1
SUM	**32**

Required bandwidth

32 bytes x 256 nodes per 1 sec

= 8192 bytes/s

Exemplary Number of possible nodes*

Grid area type	*Max. Number*
Rental houses	47
Sub-urban	105
City centre	31
Rural village	76
Maximum	105
Selected for calculations	**256**

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* Derived from different exemplary low voltage power grids in the Ahrtal valley.

Communication options

Bound to copper lines:

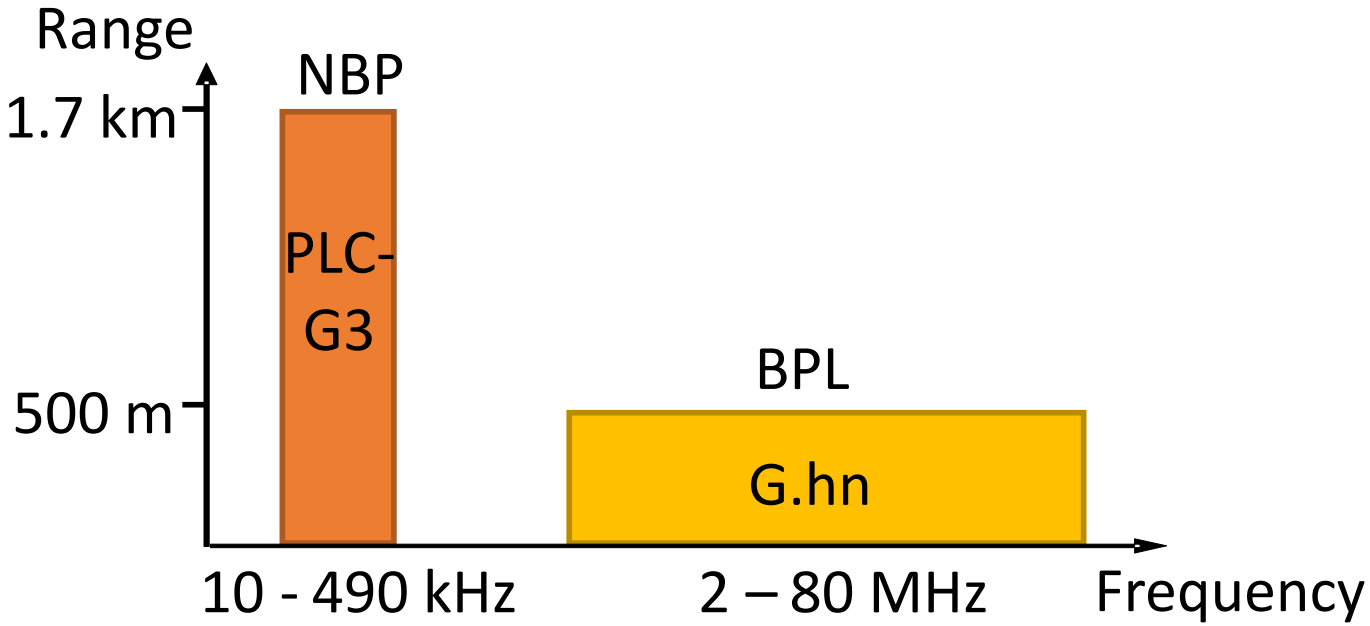
- Powerline
  - Broadband Powerline Communication (BPL)
  - Narrowband Powerline Communication (NPL)

Broadcast:

- LORA
- 5G

Powerline communication

+ No obstacles like thick walls
+ Matches with grid topology
- Filters in devices may deteriorate communication



Narrow band powerline (NPL)

- Sufficient bandwidth
- High reach
- Suitable for power grid applications

Broadband powerline (BPL)

- High bandwidth
- Low reach
- Susceptible to disturbances

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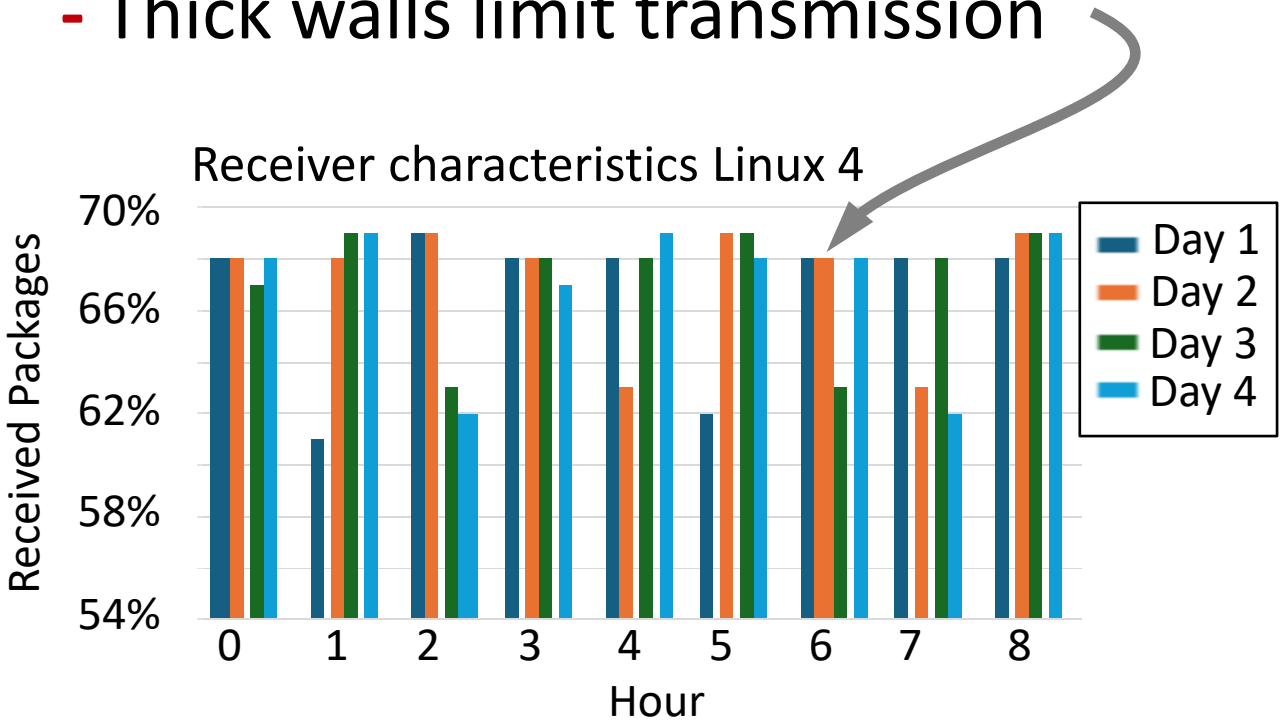
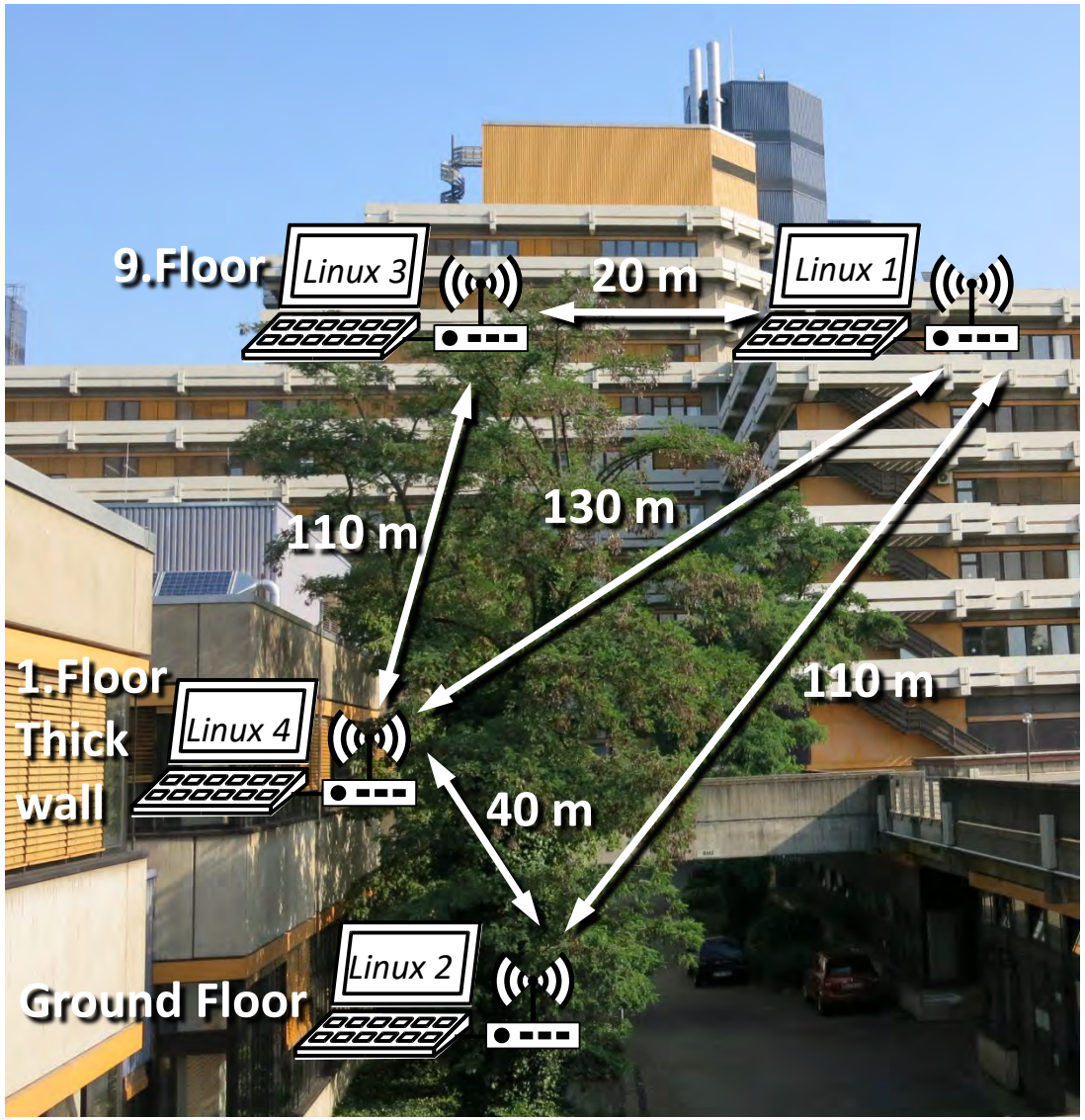
Investigations performed by:
Narrow band powerline: Lukas Mischker
Broadband powerline: Johannes Kruse

LORA

+ Peer-to-peer possible
+ Free licence
- Bandwidth shared with public users
- Thick walls limit transmission





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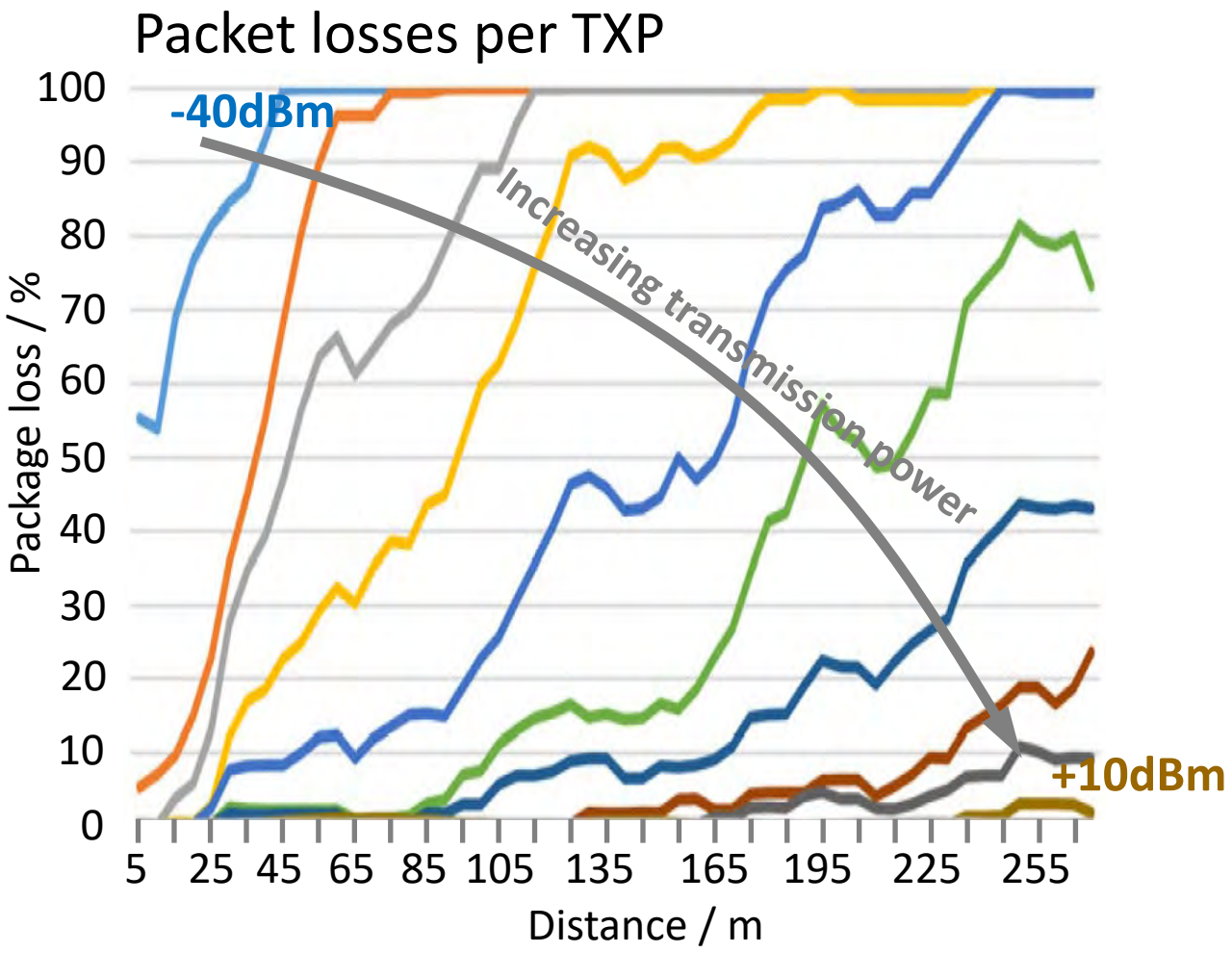
Investigations performed by
Lukas Mischker

5G

+ Peer-to-peer possible
+ High bandwidth
+ Reliable connection
  (Depending on power level)
- Thick walls limit transmission
~ Licence?



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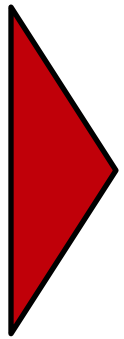
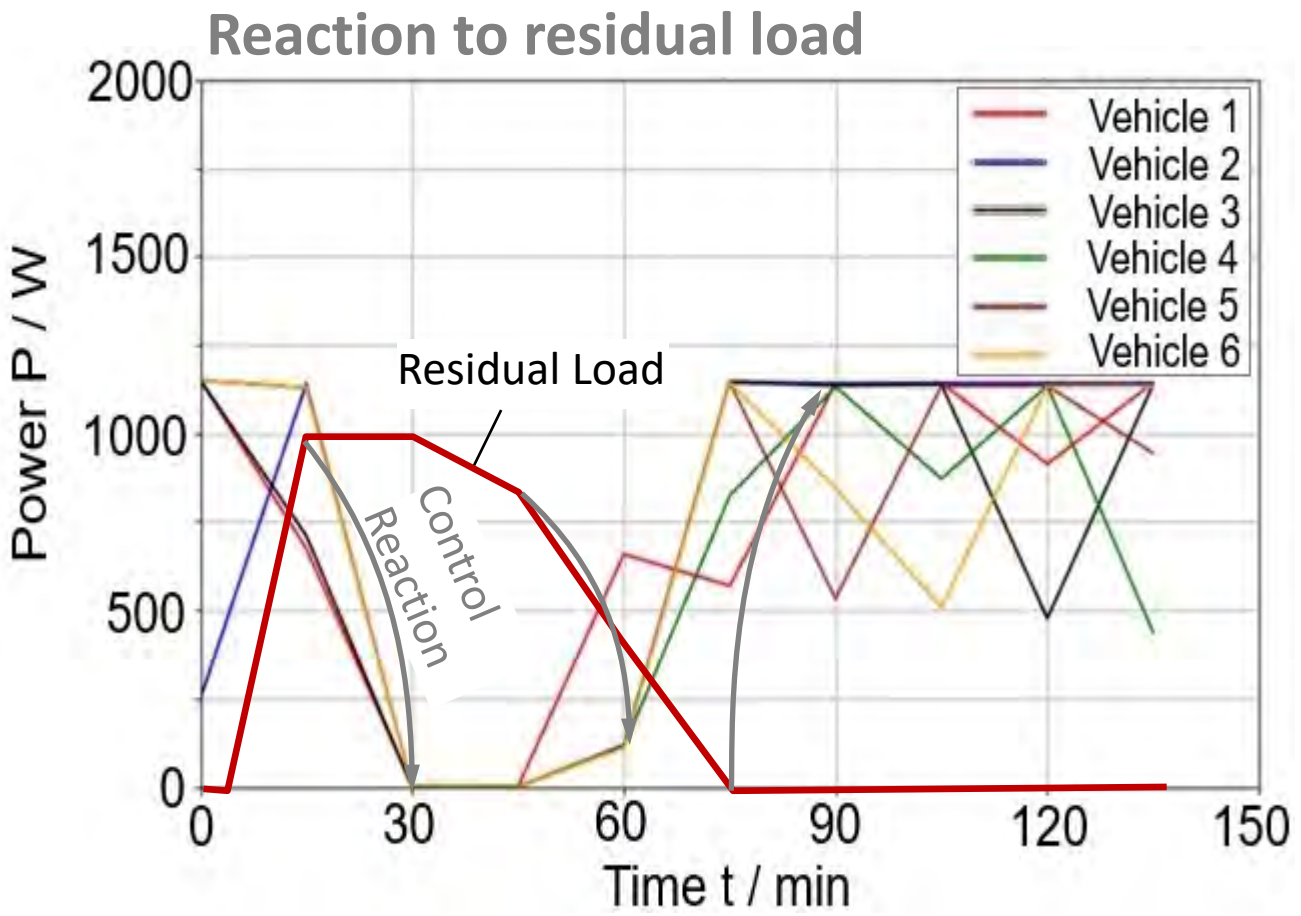
Investigations performed by
Leif Terstegen

Reaction



Optimization

- Optimal power flow
- Metaheuristic solver for
  - Multi objectives
  - Global optimum
  - Discrete parameters
- Planned power use
- Hard switching at overload conditions



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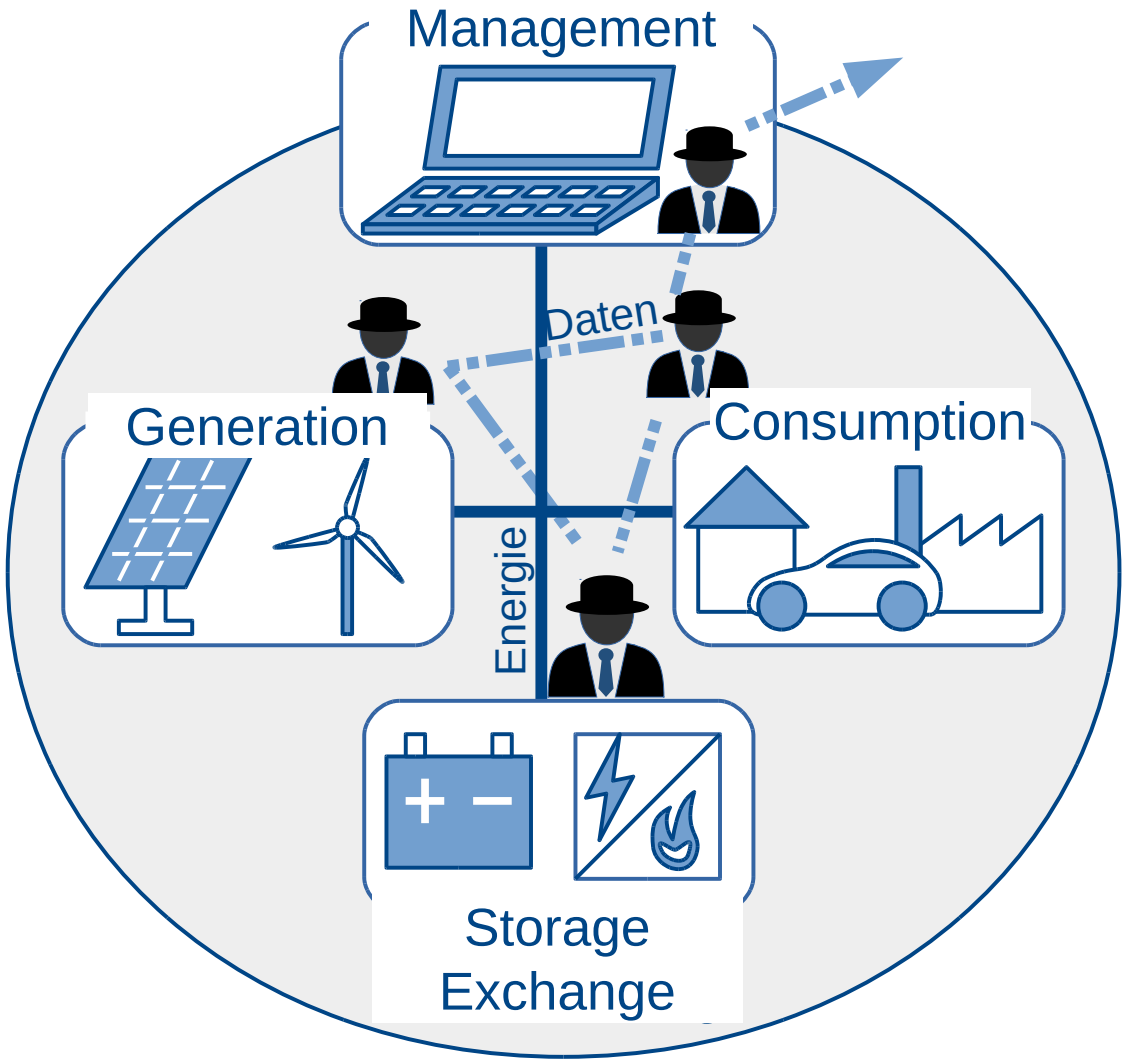
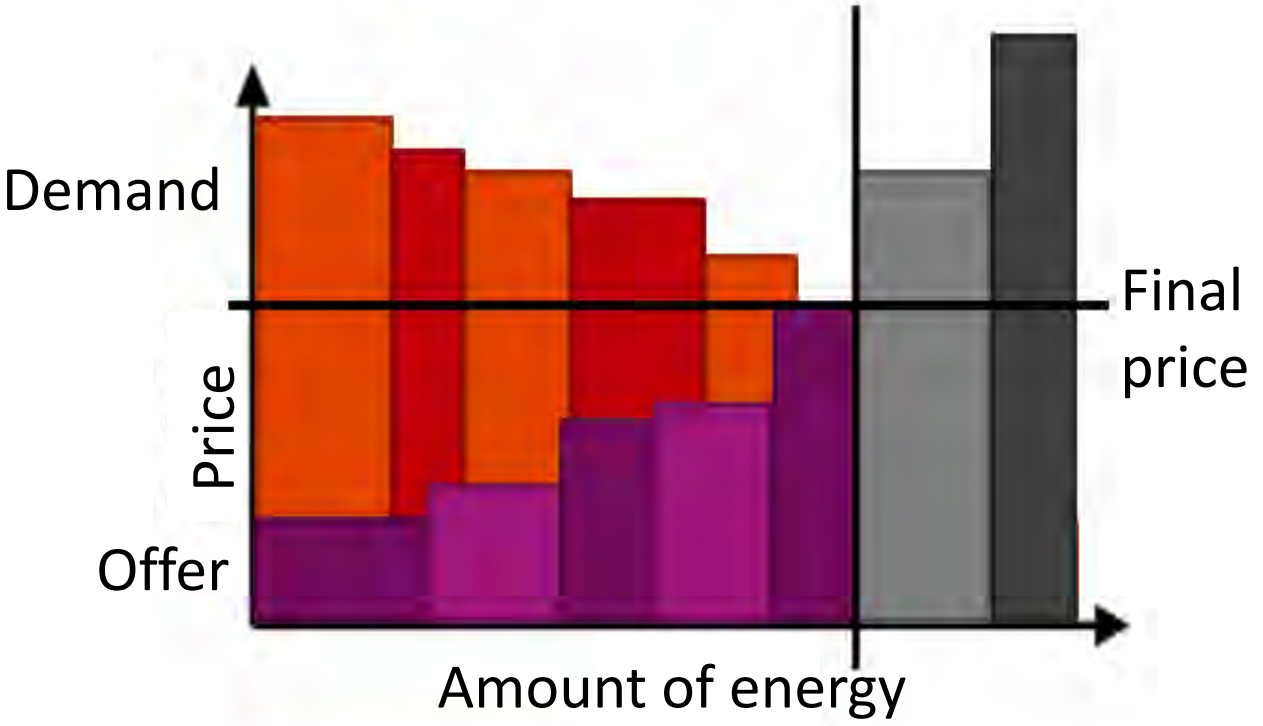
Investigations performed by André Ulrich

Energy agents in an power grid cell



Merit order principle



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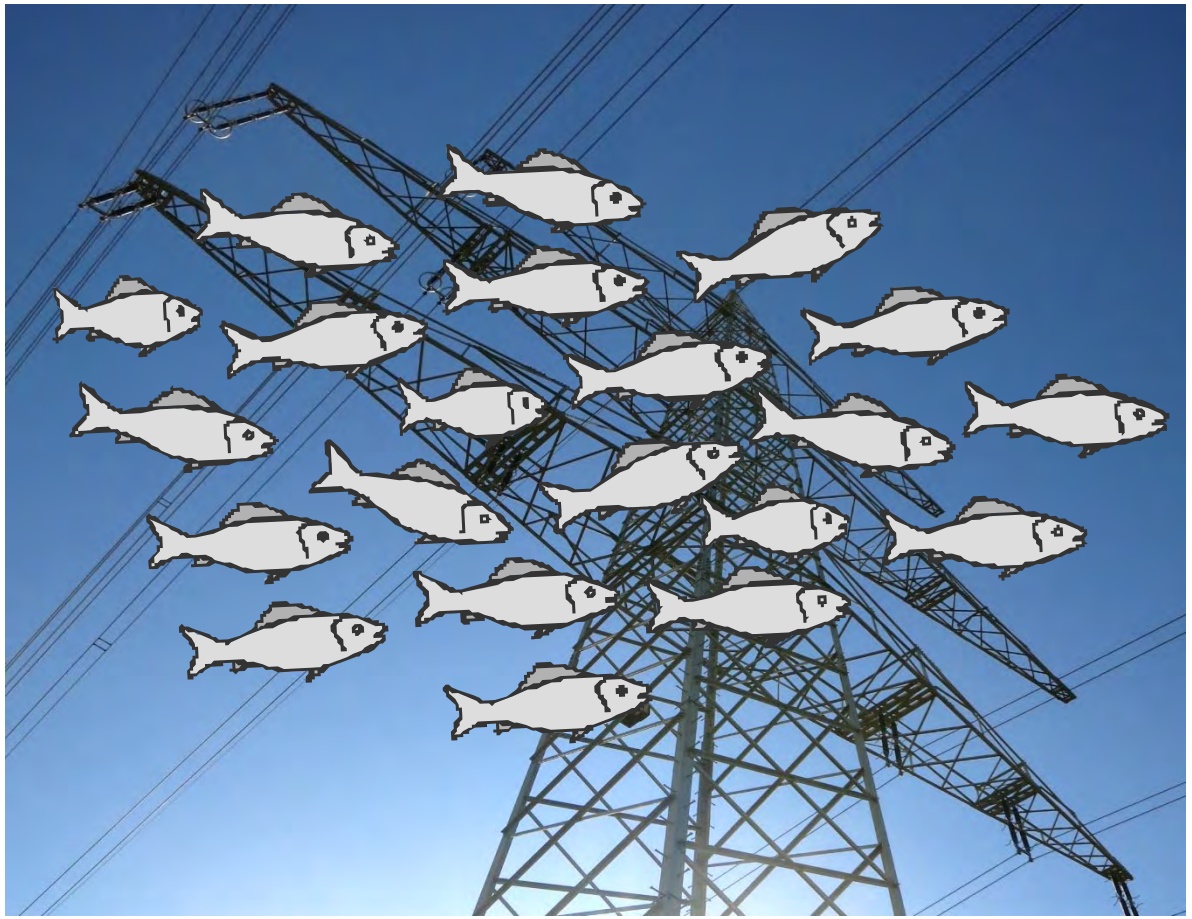
Investigations performed by
Silvan Rummeny

Conclusion

Swarm grid approach requires:

- Detection:
  - Grid state estimation
- Communication
  preferred:
  - Narrow band power line and
  - 5G
- Reaction:
  - Hard optimization at overload
  - Power grid agents to avoid overload



Next steps

Lab demonstration

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Contact and further Information

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