CRC/Transregio 154

Mathematical Modelling, Simulation and Optimization

using the Example of Gas Networks

Alexander Martin
15.03.2015

FRIEDRICH-ALEXANDER UNIVERSITÄT ERLANGEN-NÜRNBERG

HUMBOLDT-UNIVERSITÄT ZU BERLIN

TU berlin

TECHNISCHE UNIVERSITÄT DARMSTADT

UNIVERSITÄT DUISBURG ESSEN
Open-Minded

WIAS

ZIB

CRC/Transregio 154

Overview

Alexander Martin

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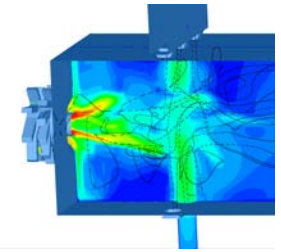
ERLANGEN-NÜRNBERG

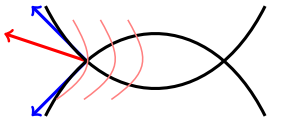
TRR
154

Mathematical modeling, simulation, and optimization

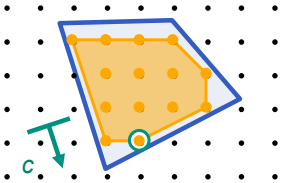
- Modeling and numerical simulation
  - existence, uniqueness, regularity
  - effizient algorithms, convergence, error control



- Nonlinear optimization and control
  - efficient algorithms, convergence, error control
  - local optima and their characterization



- Integer programming
  - globally optimal
  - analysis of the solution space



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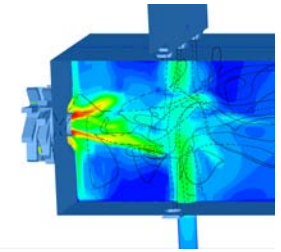

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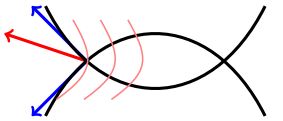

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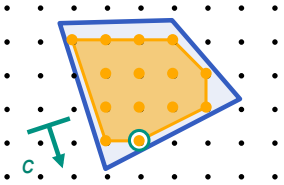

Coupling: integer and continuous

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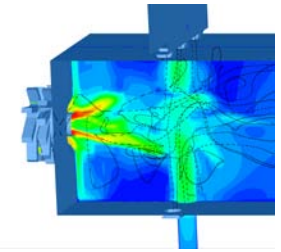

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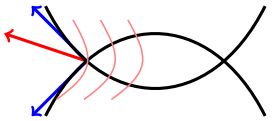

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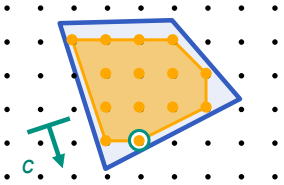

Coupling: integer and continuous

- active research area

Mathematical modeling, simulation, and optimization

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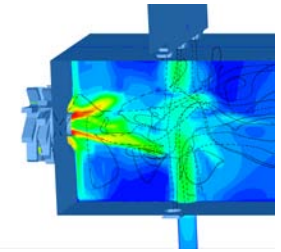

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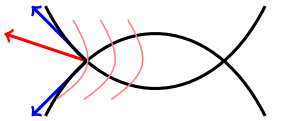

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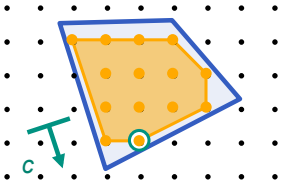

Coupling: integer and continuous with uncertainty

- active research area
- uncertain data

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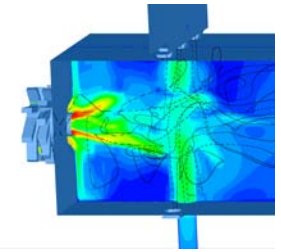

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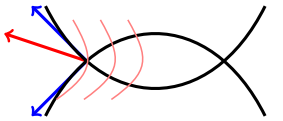

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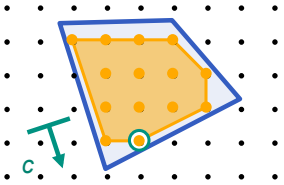

Coupling: integer and continuous with uncertainty

- active research area
- uncertain data
- general methods out-of-reach

Gas networks

- Networks are inherently discrete

  Ventil a with switching variable $s_a \in \{0, 1\}$

$$s_a = 0 \;\Rightarrow\; q_a = 0$$
$$s_a = 1 \;\Rightarrow\; p_i = p_j$$

- Physics are inherently continuous

$$\frac{\partial \rho}{\partial t} + \frac{\partial (\rho v)}{\partial x} = 0$$
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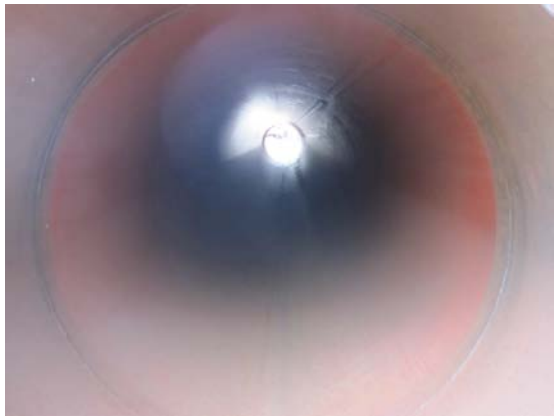

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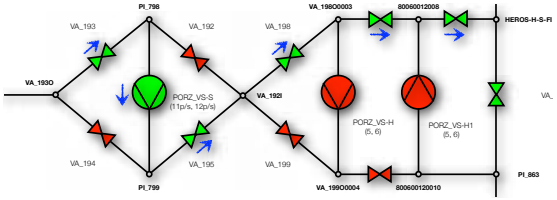

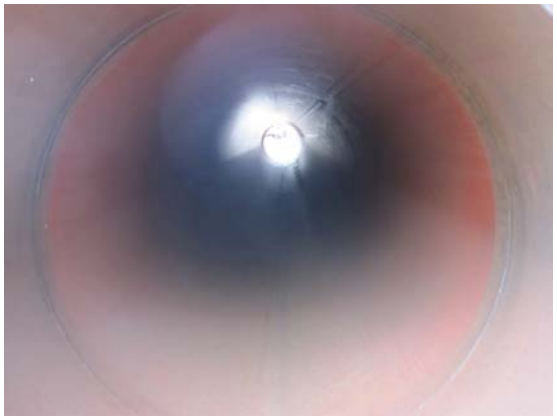

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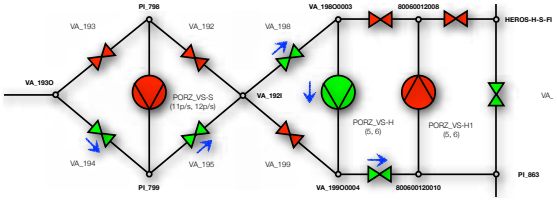

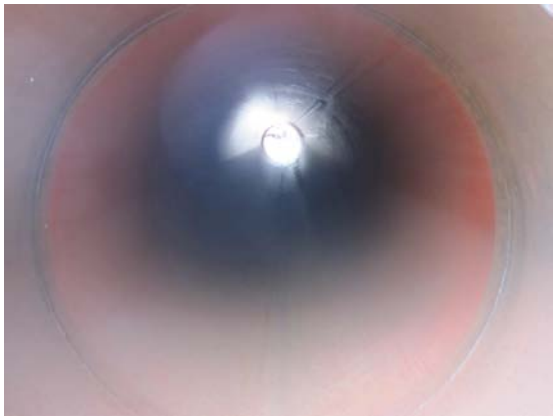

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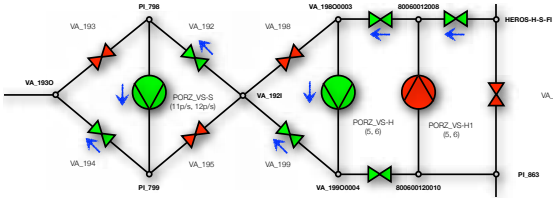
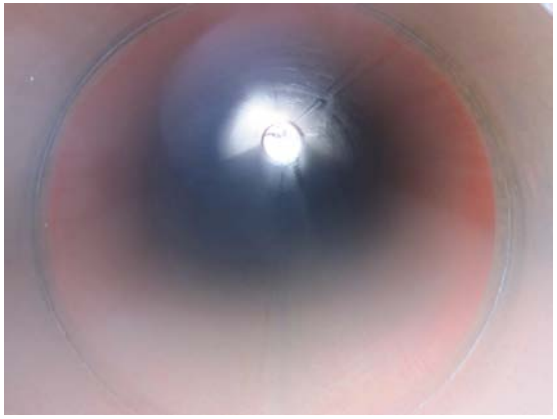
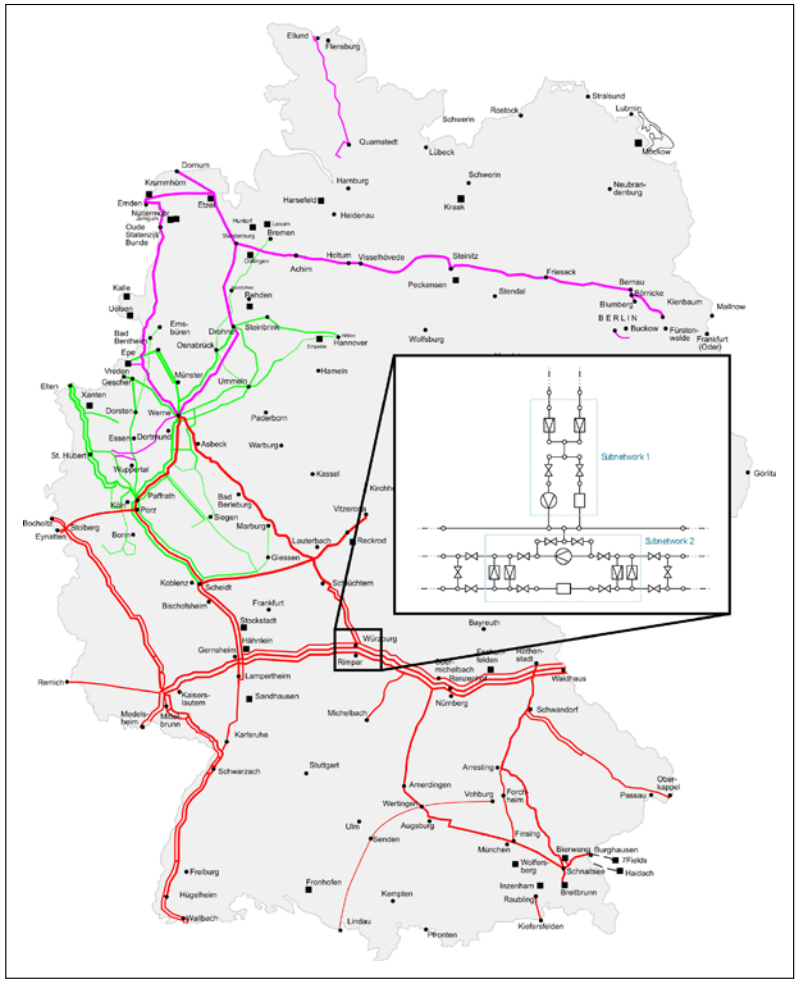




Gas networks

- Gas networks are very big



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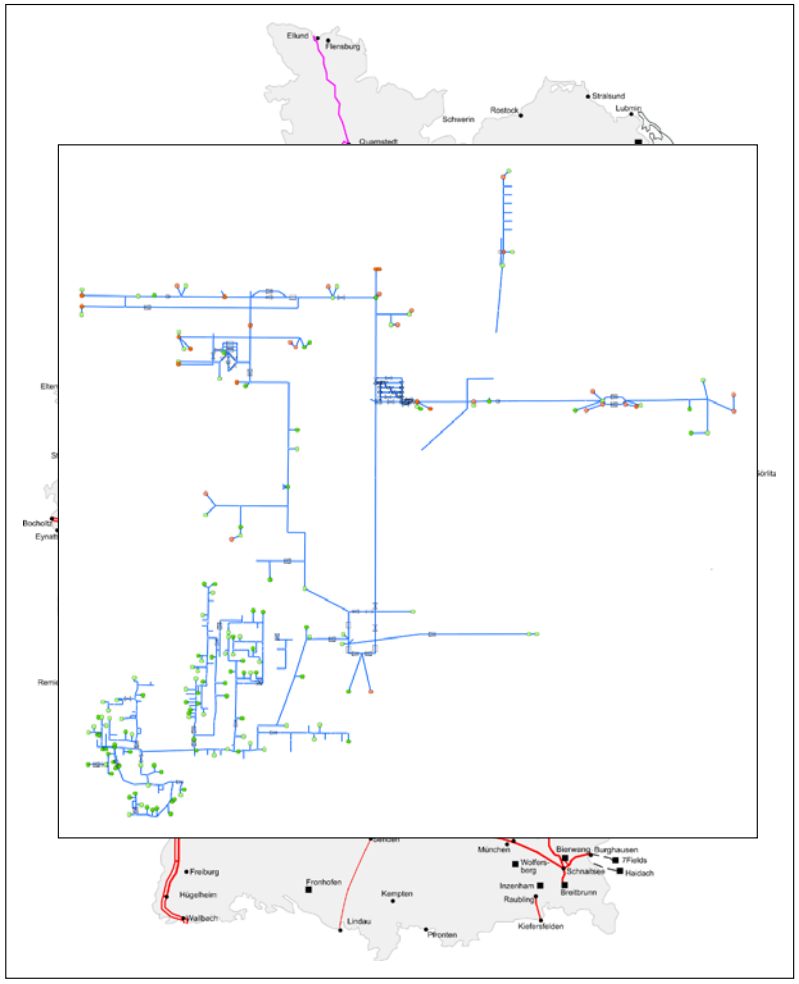

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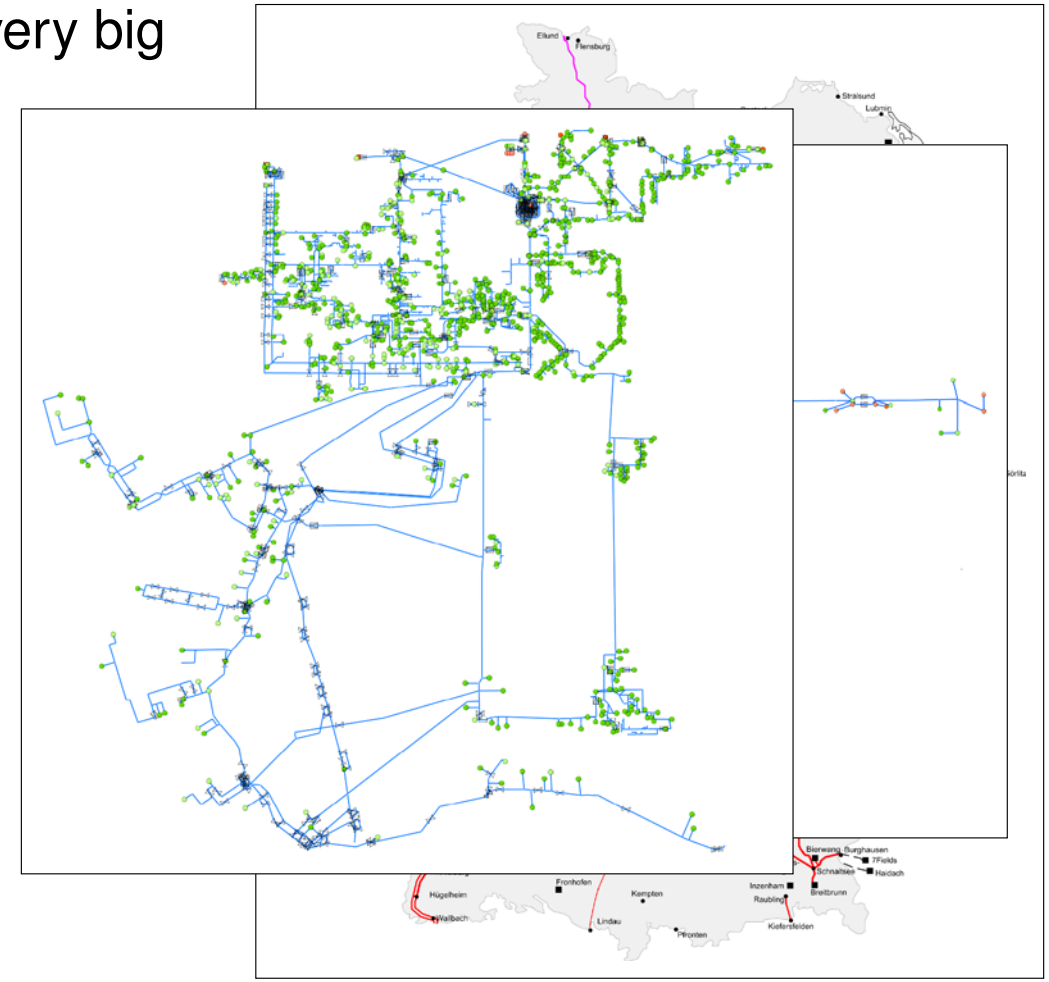

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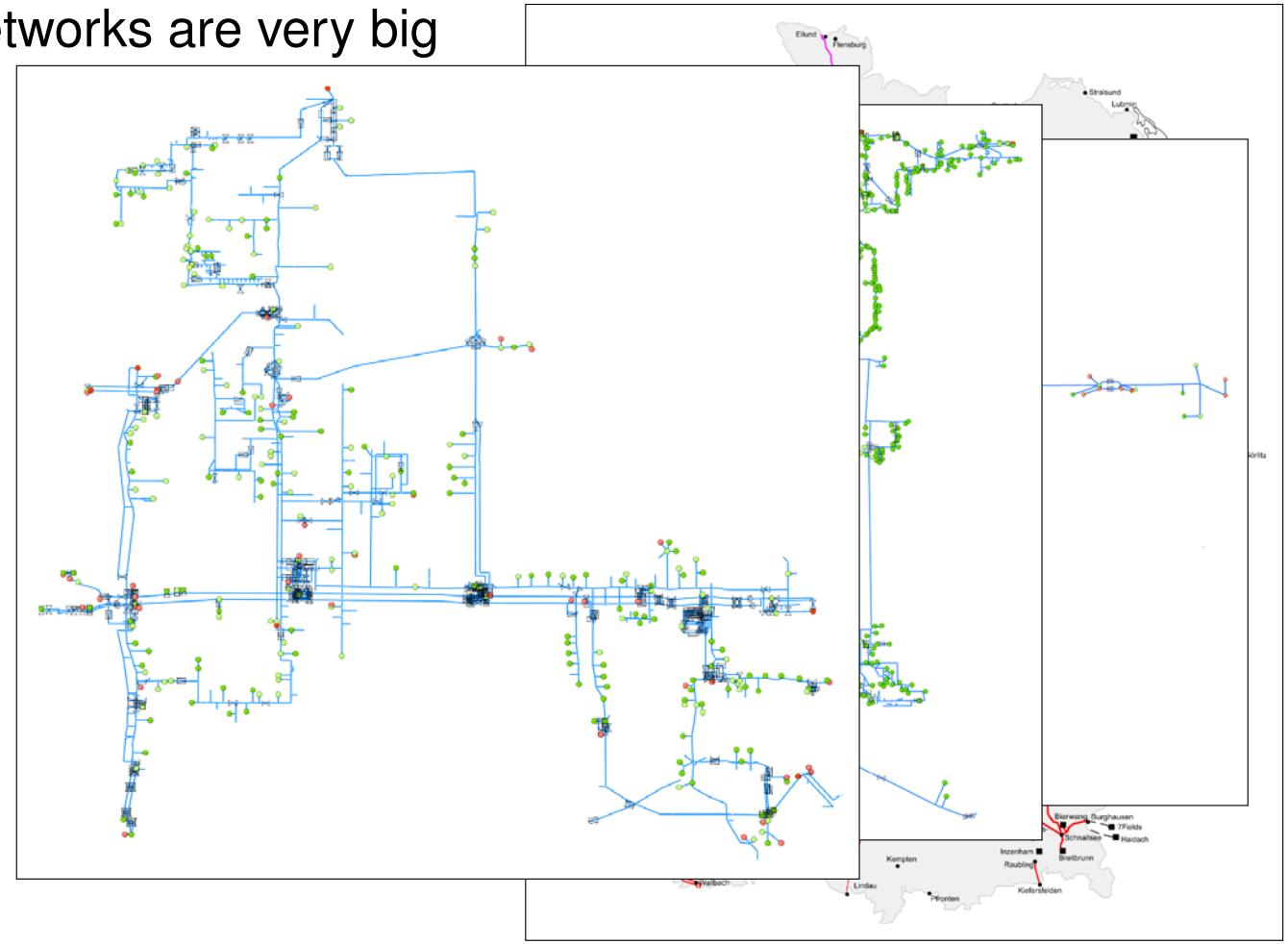
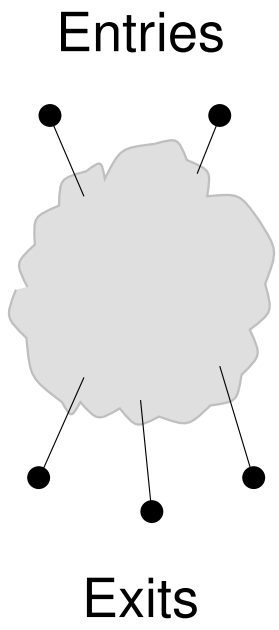


Gas networks

- Gas plays a major role in the tranformation of the energy system
- Gas . . .
  - is sufficiently available (within this time period)
  - is promptly disposable
  - is storable
  - is traded

Gas networks

- Exact methods are necessary
  - in optimization and
  - in simulation (via error estimators)



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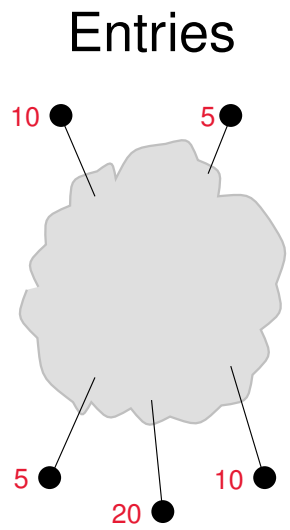

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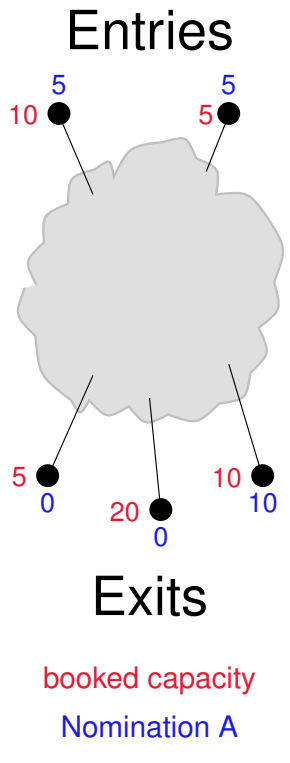

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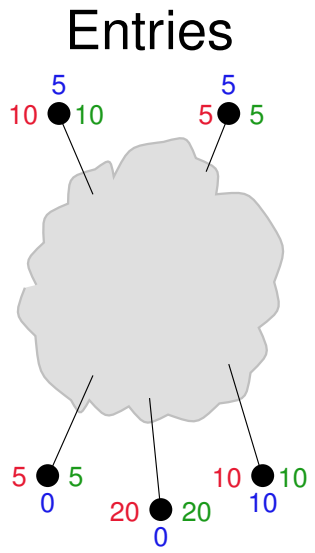

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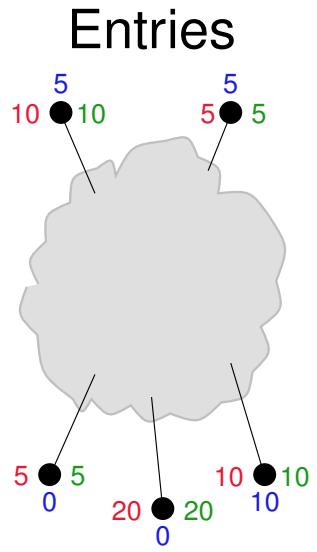
  - Market assumes stationary situations
  - Physics are instationary



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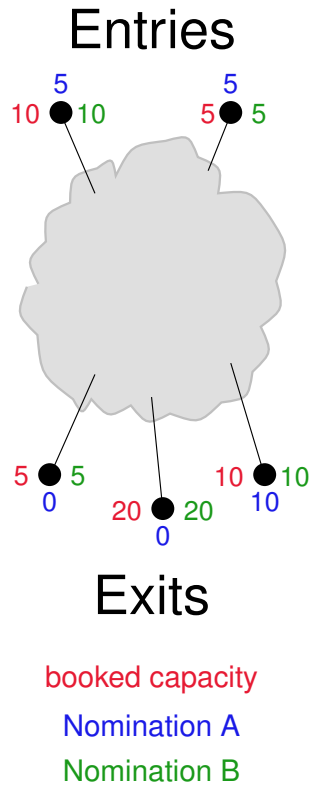
- Uncertainties
  - at the entry/exit nodes
  - in the model parameters



Mathematical questions and goals

using the example feasibility/infeasibility

In-/feasibilty of nominations

- Consistent hierarchy of models and their coupling
- Error estimators and controls
- Exact methods and their coupling

We need ...

a global mathematical understanding of the input/output behaviour of optimally controlled dynamic networks

Teamwork

- Graduate school

Teamwork

- Graduate school
- Integration in excellent existing structures
  BMS, CE, ESE, EnCN, . . .

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- common data base

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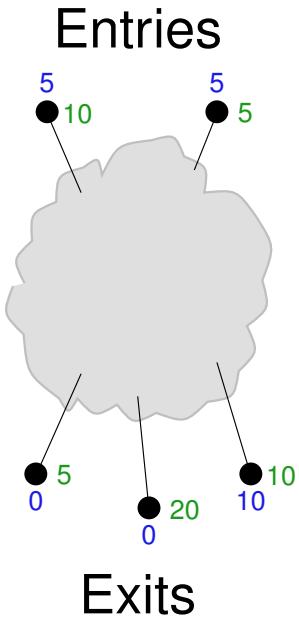
- Demonstrators

Demo	OPT MINLP	OPT ODE/PDE	SIM	Un-certainty	Model Coupling
Nomination	A07	A01, A05, B02	C02	B04, B05, C03	B03
Power Plant	A04	A02	C02, C04		A03
Storage	B07, A05	A02	B01, C04	B06	B01, B03

Berlin, Darmstadt, Erlangen, Duisburg

Teamwork within Demonstrator 1

How to get from Nomination A to Nomination B



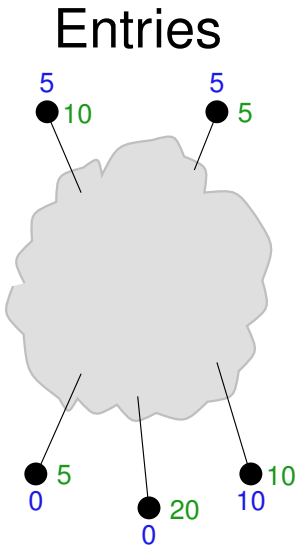
Nomination A
Nomination B

Teamwork within Demonstrator 1

How to get from Nomination A to Nomination B

stationary/instationary:

- B07/07 Combinatorial decisions (on large networks)
- A01/05 Corresponding optimal control
- C02 Physical Validation



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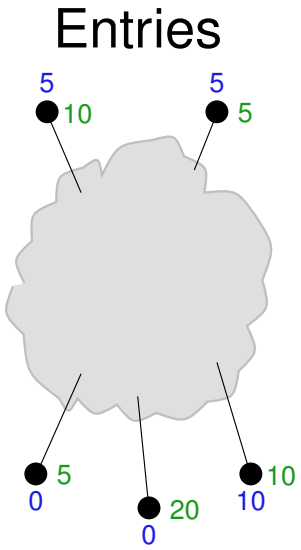
Complemented by

- C03 an analysis of reachability
- B03 regulation of the solution interfaces



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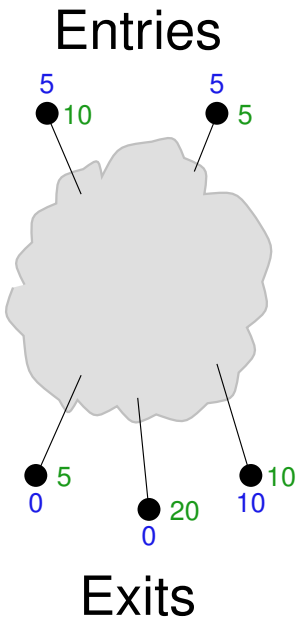
Impact of uncertainties

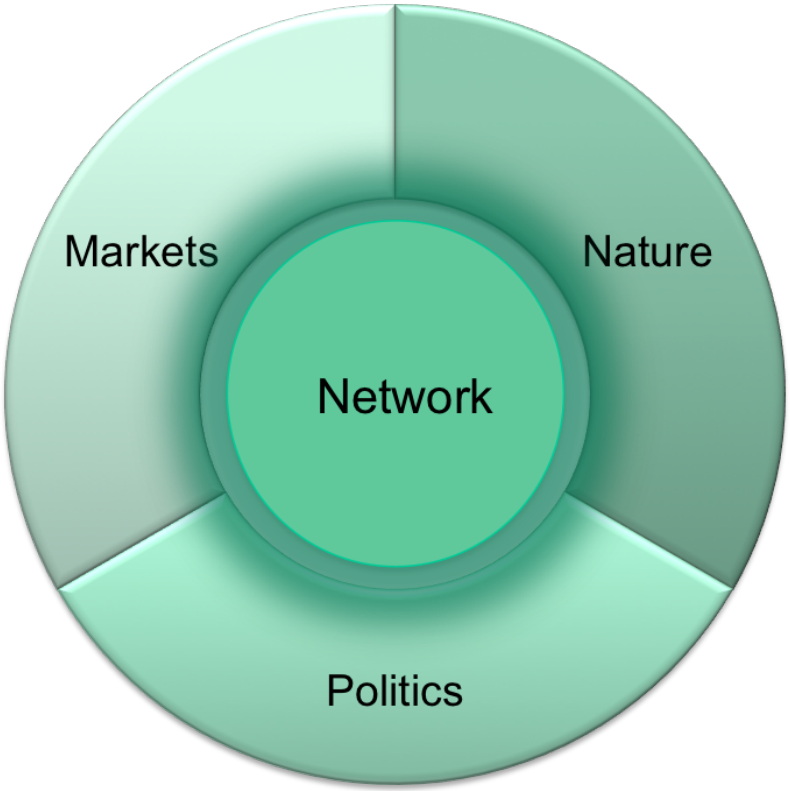
- B04/05 Existence of flows with chance constraints
- B02 Robust Identification of paramaters at small scale



Topics across projects and sites

Topic	Berlin	Darmstadt	Erlangen	Essen
Discretization	C02	C04, B01	C02	
Uncertainty	B04		B06, C03	B05, C03
Switching Systems	A03	A02	B02	
Infeasibility	A07	A01	A05, B07	
Error Estimators / Control	B03, C02	B01	C02	
Model Coupling	A04, B03	B01	A03	

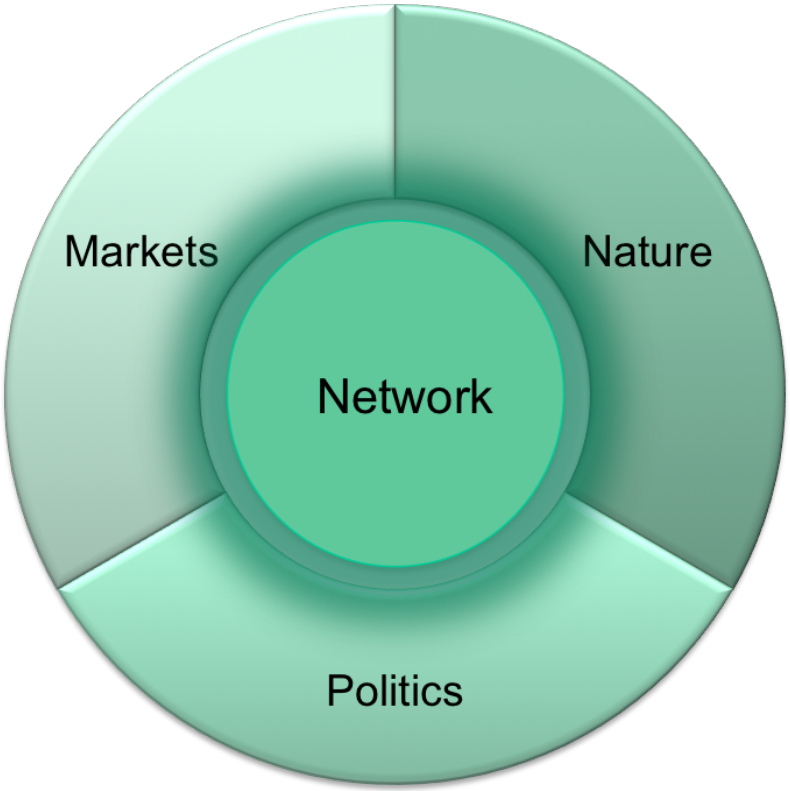
TRR 154's future



TRR 154's future

Gas networks

- Marketability
- Security of Supply



- Coupling of energy carriers

TRR 154's future

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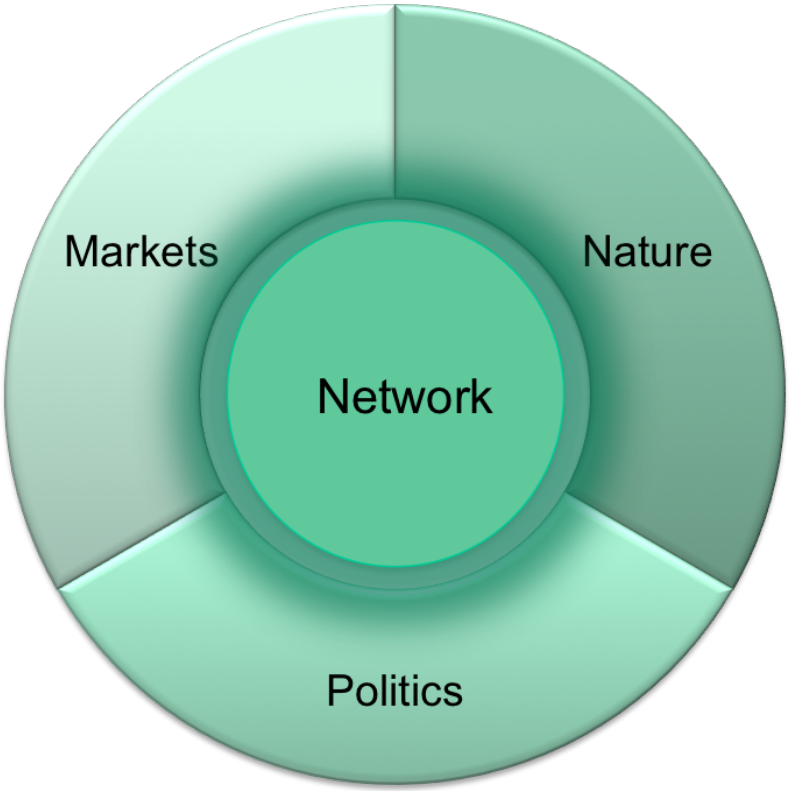

- Coupling of energy carriers

Mathematics

- Model extentions
- Increase in Complexity
- Multiscales and uncertainties
- Multilevel Optimization
- Coupling networks with physical transport