Planning of gas networks

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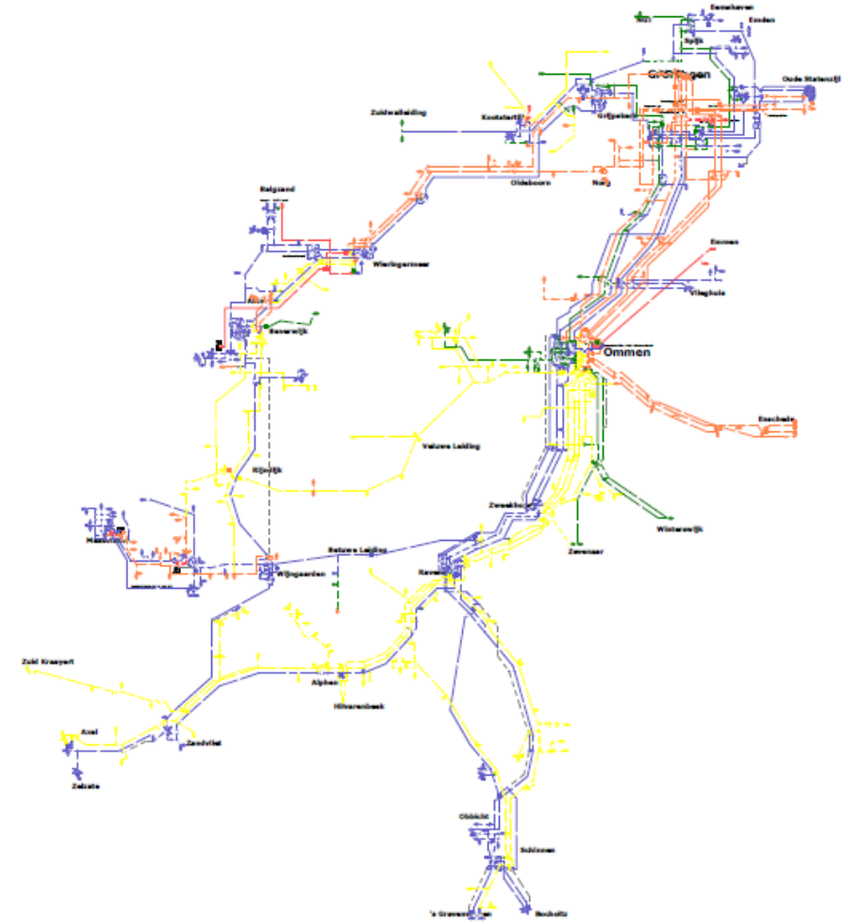
Current GTS planning methodology

- GTS high pressure network
  - serves hundreds of entries and exits
  - transports different gas qualities
- Network has to match:
  1. present contractual situation
  2. developments in the gas market
- Many combinations of entry and exit conceivable
  - too many to evaluate
- Selection needed
  - a "sufficient" set must remain
- Limited set of "shipping variants" used for transport testing
  - using market information
  - based on "expert judgement"



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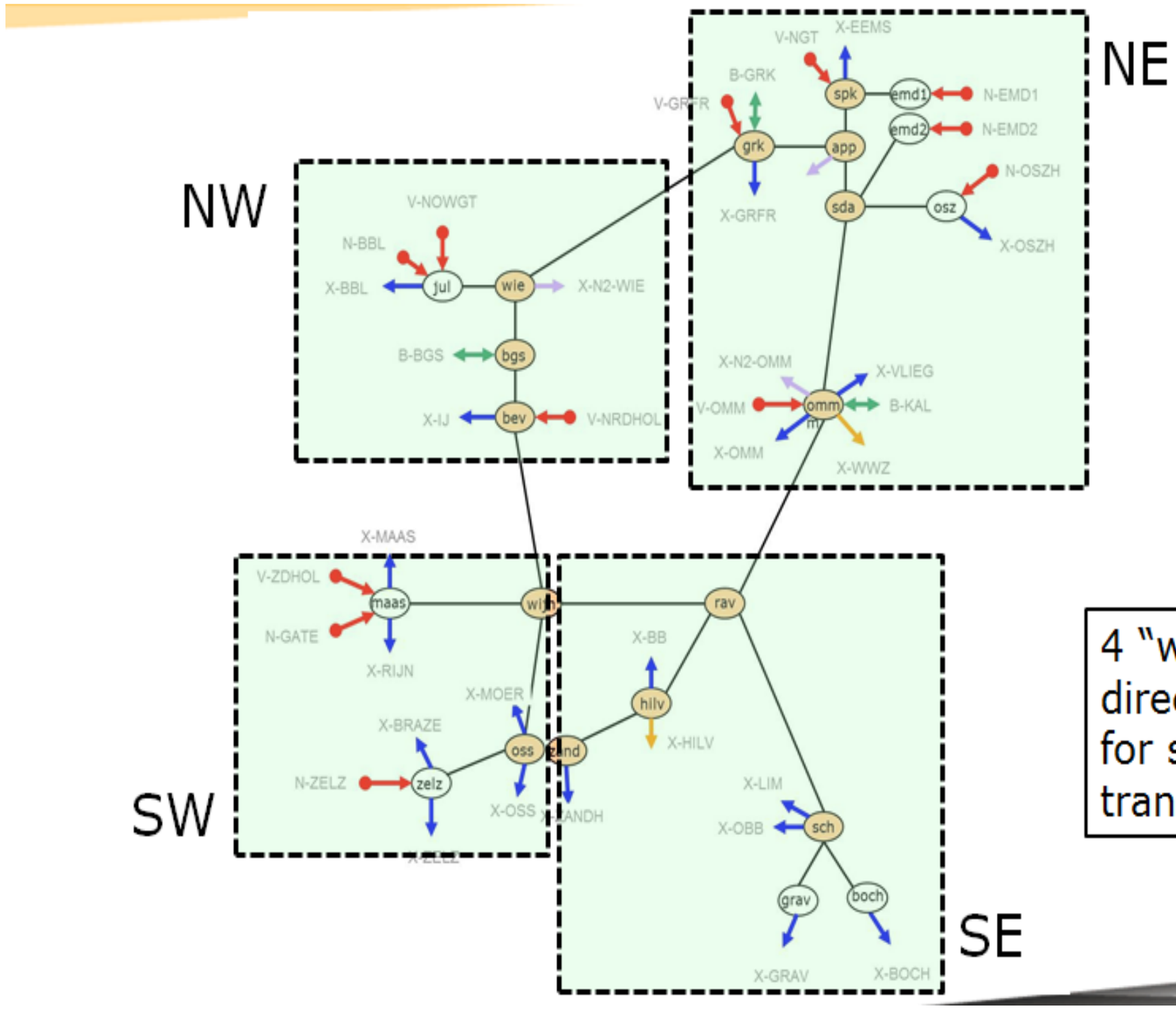
GTS hical network: clusters of entry & exit



4 "wind directions" for severe transport

Status and goal

- Status
  - Current method used for several years
    - limitations: possibly incomplete, static set
  - New challenges ahead (regulation, capacity auctions
    - substantiation and more accuracy needed
- Goal
  - Method for future use
    - robust, flexible, explicable
  - Requirements:
    - structured, objective, accurate
    - based on simple, easy to explain principles
    - leading to small, but complete set of shipping variants

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To a structured approach of shipping variants

- Any balanced combination of entries en exits defines a transport situation

- A shipping variant is a severe transport situation
  - within contractual limits
  - describing realistic market behaviour
  - that determines the network configuration

- Transportation theory → amount of transport depends on
  - transported quantity (flow Q)
  - transport distance (L)

- Relevant parameters
  - transport moment $\sum_i Q_i . L_i$
  - complex network → various severe cases (directions)

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Recipe for generating shipping variants

1. Choose reference point
2. Draw up distance table of entries and exits (w.r.t. this point)
3. Take list of capacities (i.e., all N_i and X_j)
4. Maximise transport moment for entry and exit centres

$$\sum_i X_i D_{X_i} - \sum_i N_i D_{N_i}$$

subject to balance constraint

$$\sum_i X_i = \sum_i N_i$$

5. Keep resulting NX-combination (= shipping variant)
6. Repeat for all reference points
7. Reduce resulting set
   (identify identical, similar cases; delete milder cases)

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Results for GTS hical network

- 28 Shipping variants for simplified hical network
- Reduction possible, based on similarity of

  shipping variants represented as “entry/exit-vectors” $(N_1, \dots, N_m, X_1, \dots, X_{N-m})$
- E.g. cosine similarity in N-dimensional Euclidean space:

$$\cos\theta = \frac{<x,y>}{||x||\cdot||y||}$$

- Skipping identical shipping variants → 13 remaining
- Further reduction may be possible, depending on similarity criterion
  - e.g. $\cos\theta > 0.9$ → 7 different shipping variants remaining

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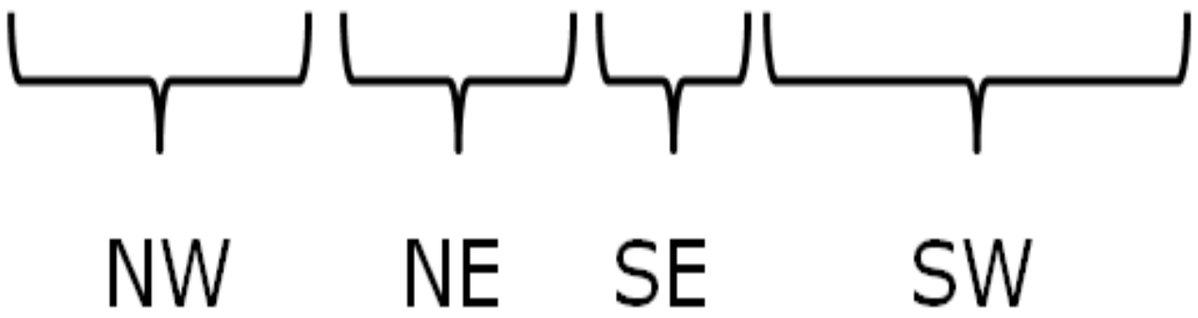
Results of further reduction

	R1	R4	R5	R11	R21	R17	R6	R3	R19	R8	R22	R13	R12
R1	1.00	1.00	0.90	0.73	0.65	0.39	0.05	0.04	0.62	0.47	0.47	0.49	0.30
R4	1.00	1.00	0.90	0.73	0.65	0.39	0.06	0.05	0.62	0.48	0.48	0.50	0.31
R5	0.90	0.90	1.00	0.63	0.54	0.25	0.02	0.00	0.74	0.59	0.59	0.61	0.42
R11	0.73	0.73	0.63	1.00	0.98	0.81	0.61	0.58	0.30	0.15	0.15	0.17	0.14
R21	0.65	0.65	0.54	0.98	1.00	0.88	0.70	0.67	0.26	0.15	0.15	0.17	0.14
R17	0.39	0.39	0.25	0.81	0.88	1.00	0.80	0.76	0.03	0.00	0.00	0.20	0.16
R6	0.05	0.06	0.02	0.61	0.70	0.80	1.00	0.98	0.06	0.07	0.07	0.07	0.26
R3	0.04	0.05	0.00	0.58	0.67	0.76	0.98	1.00	0.09	0.10	0.10	0.10	0.32
R19	0.62	0.62	0.74	0.30	0.26	0.03	0.06	0.09	1.00	0.95	0.95	0.68	0.70
R8	0.47	0.48	0.59	0.15	0.15	0.00	0.07	0.10	0.95	1.00	1.00	0.72	0.74
R22	0.47	0.48	0.59	0.15	0.15	0.00	0.07	0.10	0.95	1.00	1.00	0.73	0.75
R13	0.49	0.50	0.61	0.17	0.17	0.20	0.07	0.10	0.68	0.72	0.73	1.00	0.73
R12	0.30	0.31	0.42	0.14	0.14	0.16	0.26	0.32	0.70	0.74	0.75	0.73	1.00



- Main transport directions visible
- Known shipping variants found
- Within-cluster variations distinguishable

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Summary

- New method developed for generating shipping variants in GTS network
  - structured, objective
  - based on simple principles
  - generates small sets (that can be handled well)
  - reproduces known shipping variants
- Method looks promising for GTS network
- Further study needed
  - rings and spanning trees
  - completeness of resulting set
  - set reduction (identification of similar and milder cases)

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