Pre-runtime scheduling of avionic systems: A win-win industry-academia collaboration

Elina Rönnberg
Saab and Division of Optimization,
Department of Mathematics, LiU

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What is my presentation about?

An example of how research and development in one area of technology calls for research in another

- Describe my area of research
- Introduce the topic of research provided by Saab

- Explain how we have formulated a joint research project
- Describe how we handle the collaboration in practice

- Provide some preliminary results and lessons learned

Operations reseach / Optimisation

- Operations Research:
  advanced analytical methods to help make better decisions
  - mathematical modeling
  - statistical analysis
  - mathematical optimisation

  Search for optimal or near-optimal solutions to complex decision-making problems

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- Mathematical optimisation / mathematical programming: select a best element from some set of available alternatives
  - Find a shortest path or transportation routes
  - Production and inventory levels
  - Mechanical construction, etc ...
- Different types of mathematics in different areas

Discrete optimisation

- Decisions: yes/no, either/or, discrete quantities
- Typically NP-hard problems
  - Some can be solved within reasonable time by standard approaches and commercial solvers
  - Some cannot ...
- Research: Push the limit for which problems that can be solved
- Key: Understand and exploit structure of the problem

My area of research

Discrete optimisation

- Scheduling and resource allocation
  - Healthcare applications (nurse scheduling, treatment planning)
  - Scheduling in telecommunications network
  - Open-pit mining
  - Portfolio optimisation
- Decomposition methods
  - Column generation
  - Benders decomposition

- Preferably: Relevant to society / industry
- Emphasis on the term *decision support*

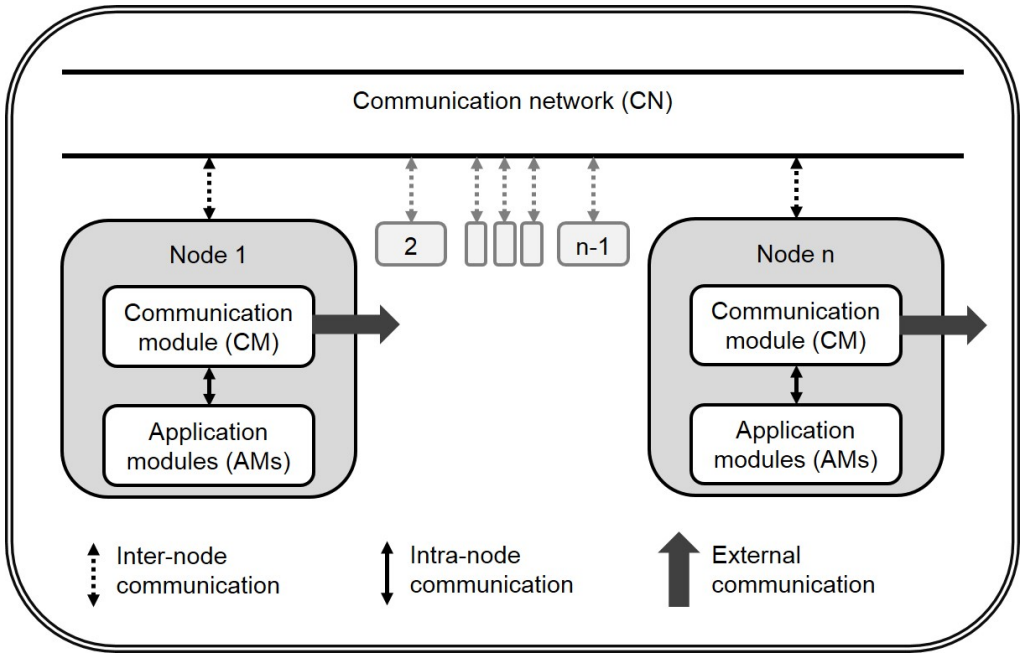
Industrial need

Avionics: electronics within an aeroplane

- sensors that gather information
- units where information is processed
- actuators that control the aeroplane
- equipment that presents information to the pilot

Saab develops avionic systems for future aeroplanes

An avionic system



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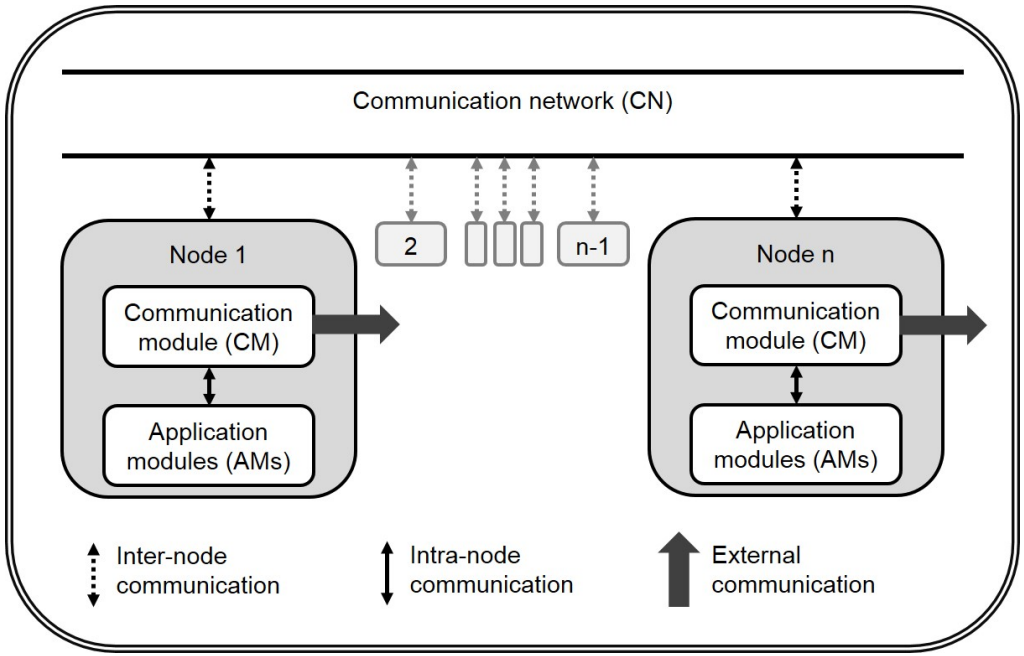
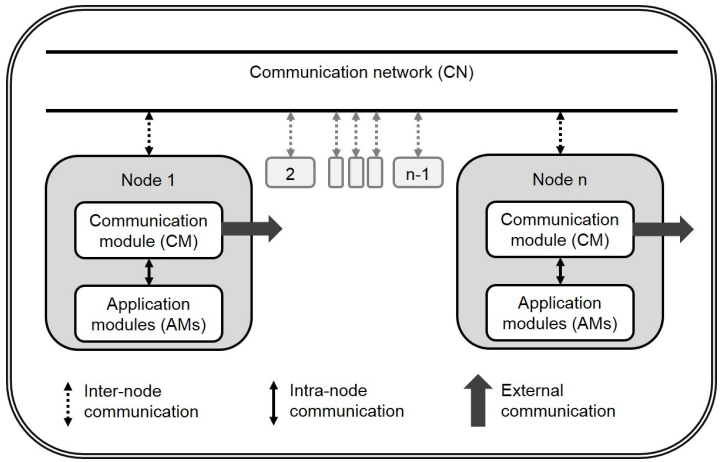


Temporal and spatial partitioning

- Spatial: Decide where to perform a Task (by engineers)
- Temporal: Decide when to perform a Task

Challenge

- Communication network
  - Assign $\sim$ 100 messages to timeslots
- Application modules:
  - Run applications
  - 8 AMs
  - 25 partitions $\times$64 repetitions
- Communication modules:
  - Three types of communication
  - 7 CMs
  - $\sim$ 20 000 tasks



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How create a temporal partitioning?

How, why and when?

For a certain project / avionic platform

- New software functionality is added iteratively
- Create a new schedule in each iteration

- Difficult to know in advance if a feasible schedule exists or not

- Scheduling tool
  - Find a feasible schedule when it exists
  - Detect if no feasible schedule exists

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- Conclusion:
  To accommodate needs, new methods are needed
  - Use decomposition techniques to have guarantees
  - Combine with other methods

How collaborate to solve this problem?

1. Involve the right people
2. Specify the research topic

People

LiU: MAI /OPT

$$
\begin{aligned}
\min \quad & \sum_{(i,j)\in A}\sum_{k\in V} c_{ij} z_{ijk} \\
\text{s.t.} \quad & \sum_{k\in V} y_{ik} \geq 1 && i \in C \\
& \sum_{(i,j)\in A} z_{ijk} = y_{ik} && i \in N,\ k \in V \\
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SAAB

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Programmer

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Steering group:

- Technical fellow: Ingemar Söderquist (Electronics design in avionics)
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- Managers from Saab

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Funding:

- CENIIT
- Research school in interdisciplinary mathematics

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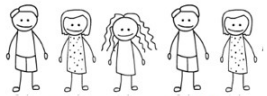

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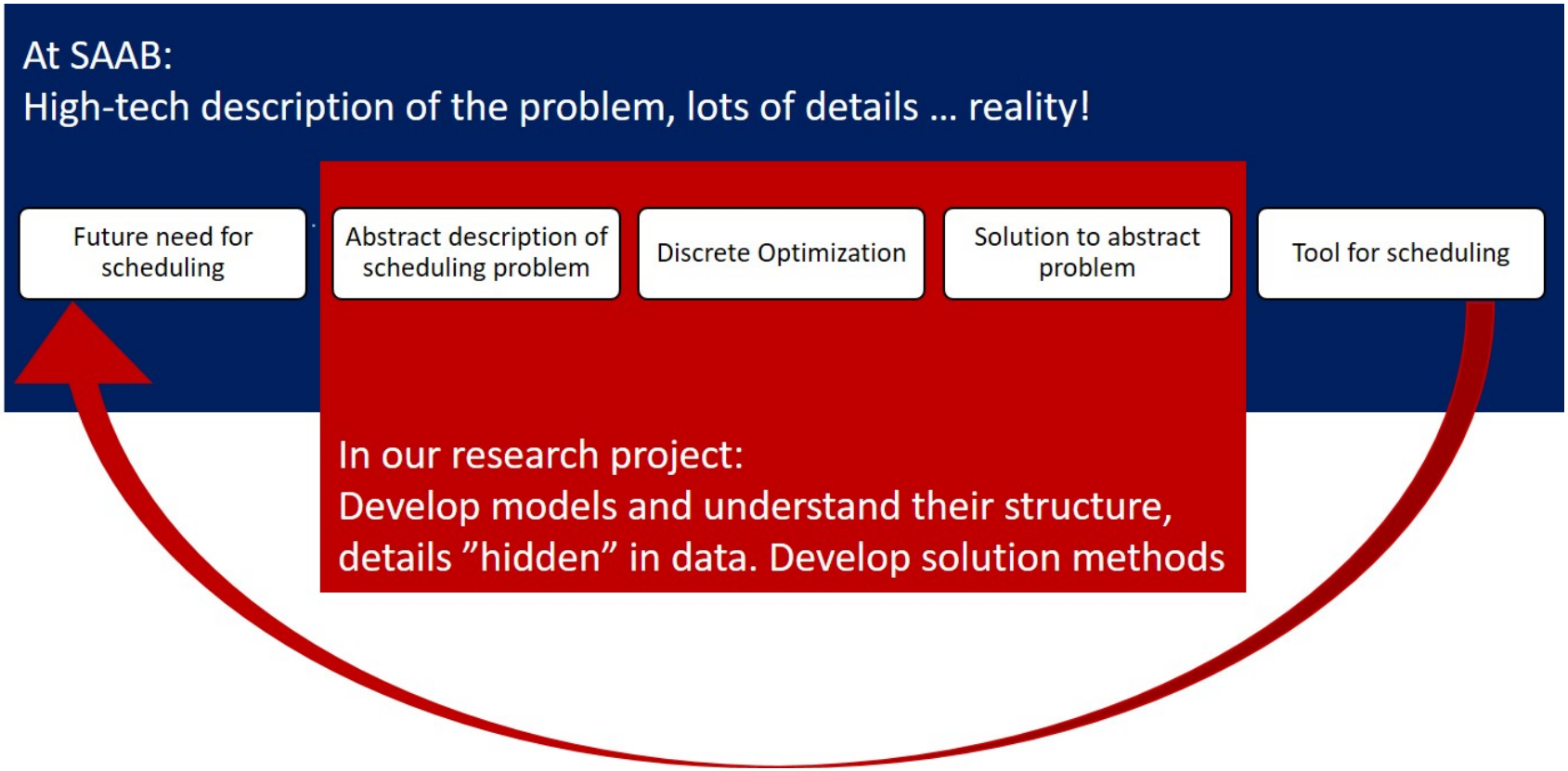
NFFP/INNOVAIR cluster Avionic Platform Technology

Project


At SAAB:
High-tech description of the problem, lots of details ... reality!
Future need for scheduling
Abstract description of scheduling problem
Discrete Optimization
Solution to abstract problem
Tool for scheduling
In our research project:
Develop models and understand their structure, details ”hidden” in data. Develop solution methods

Some results

Instance	A	B	C
Number of binary variables	$33 \cdot 10^6$	$81 \cdot 10^6$	$114 \cdot 10^6$

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Solution times	$<$ 2 min	14 min	19 min

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Win-win and *lessons learned* (preliminary)

LiU: Interesting topic for research, results can be generalised

Saab: Meet future needs

- Organisation is crucial!
  Steering group = access to the right people
- Parallel planning
  - Publications
  - Deliveries to Saab to show progress
- Clear goal:
  +: The direction of the research is clear
  −: Achievements always compared to the industrial ambition

Conclusions and continued research

- Collaboration is established
- Research topic is defined, goals are set
- A first delivery:
  - Paper to be submitted
  - A first scheduling tool for Saab
- Next step: Enhance computational performance
  Twice the size in half the time? ;-)

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Thanks for listening!