TRAIN DISPATCHING

-THE IRON ORE LINE

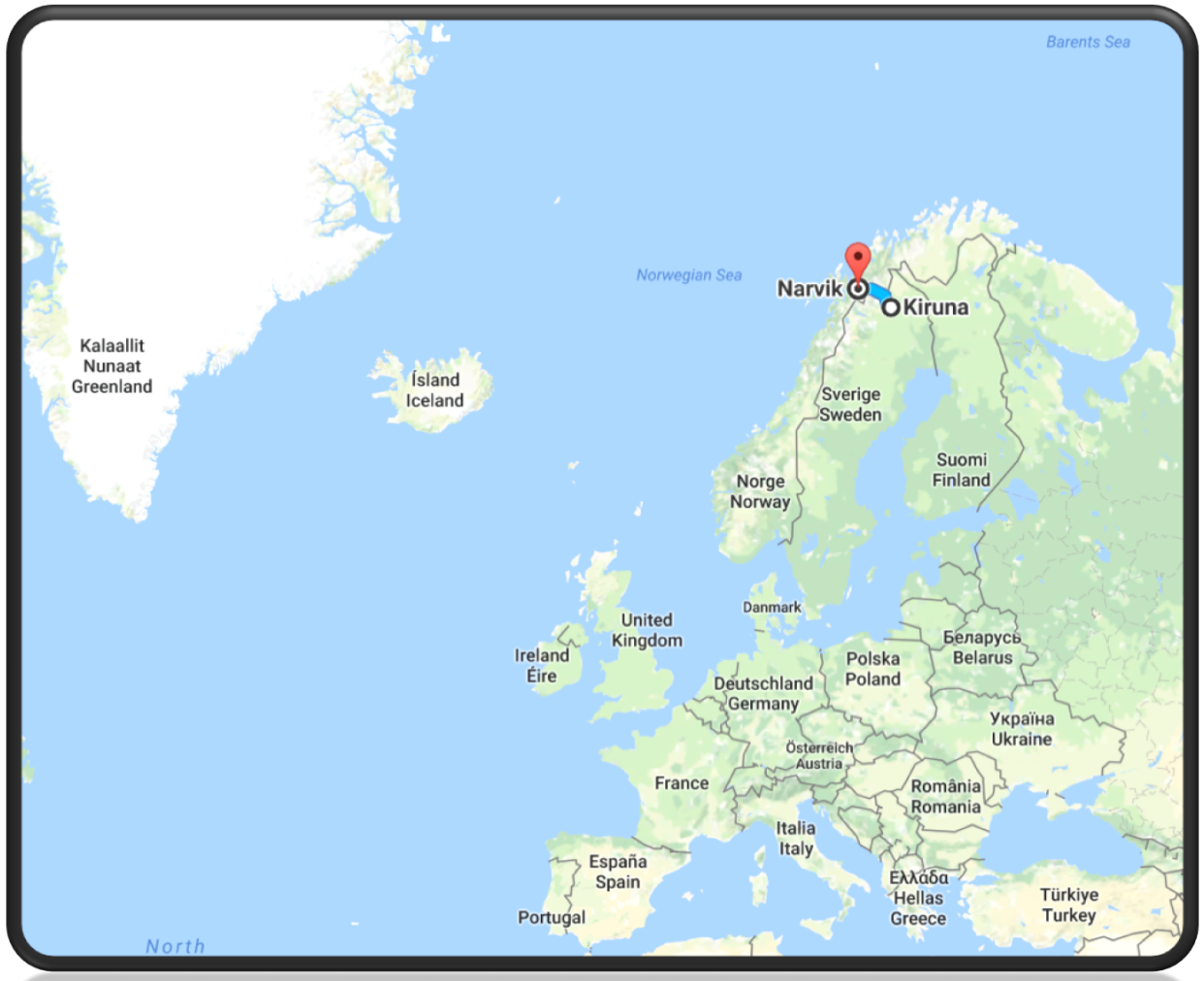
Lukas Bach, Oddvar Kloster, Carlo Mannino

Agenda

1. Case description
2. Dispatching
3. Algorithm
4. Status and demo

Case description

- Approximately 170 km. single track railway line.
- Mainly used for iron ore.
- Limited capacity, high and increasing demand.
- Mountainous region.



SINTEF

Traffic

- Iron ore trains: Approx. 20/day
- Passenger trains: 4/day, will be 6/day
- Freight trains
- Service trains

LKAB shunting yard

Meeting trains

SINTEF

What is train dispatching?

- Train dispatching is done by human operators (*dispatchers*) located at various dispatching centrals.
- Dispatchers control railway traffic by switches, traffic lights, phone calls etc.
- When trains deviate from the official timetable, dispatchers must take re-routing and re-scheduling decisions.
- The target is to alleviate overall delays, knock on effects and to return to the official timetable as soon as possible.

How has train dispatching traditionally been done?

- Each dispatching central is responsible for the train movements in a region.
- Each dispatcher is responsible for a line or parts of a line that is under the control of the given central.
- Train dispatching typically follows predetermined rules.
- A dispatcher can deviate from the rules if he/she thinks that is the best way of solving the problem.

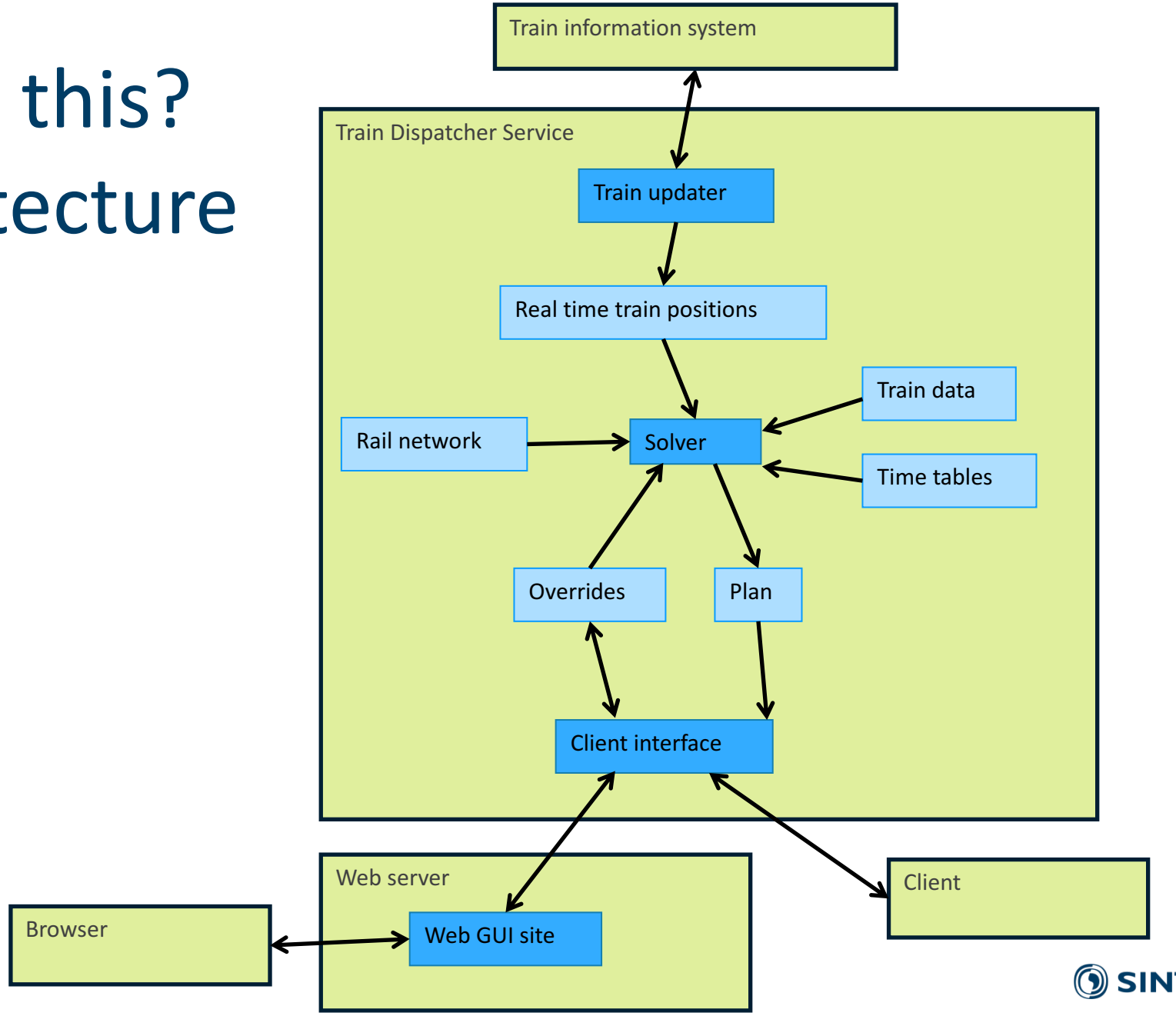
Iron Ore Line – current state

- Crossborder dispatching
- Swedish dispatching in Boden
  - Serves larger part of Sweden
- Norwegian dispatching in Narvik
  - Dedicated to the Norwegian part of the line (approx 40 km.)
- LKAB
  - Dispatches trains onto the line in Kiruna and Narvik

Decision support for dispatching

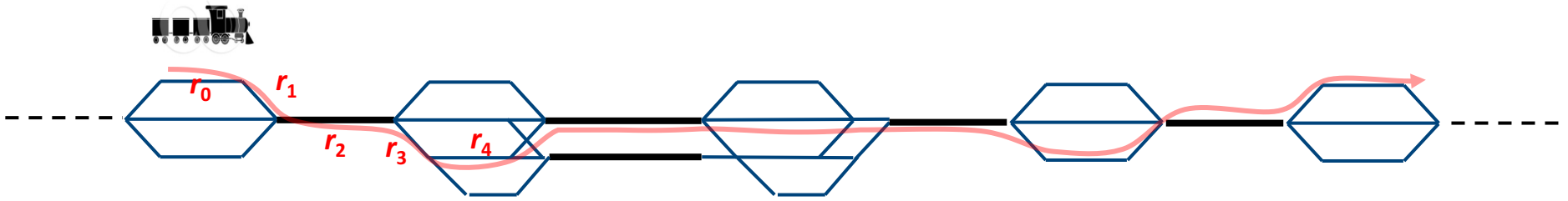
- Our tool receives real-time information on the network and the trains
- Considers the whole geographical area
- Takes optimal dispatching decisions
  - Minimize total cost (primarily delays)
- Show the suggested schedule

How do we do this? -Current architecture



SINTEF

Modelling train movements

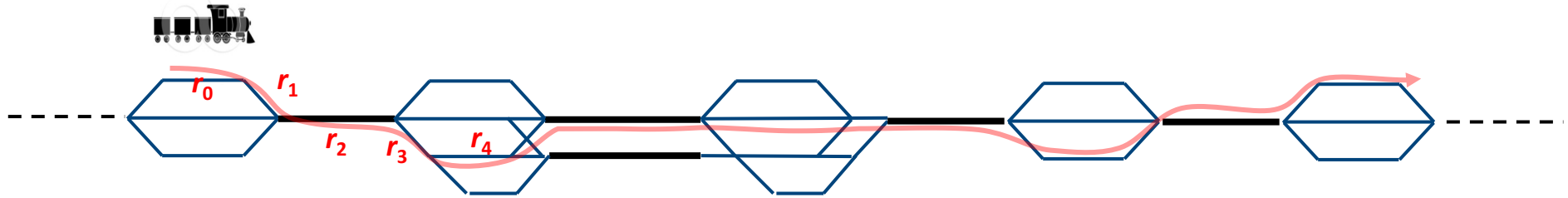


- ***Atomic movement*** $u = (i,r)$: occupation of rail resource r by train i

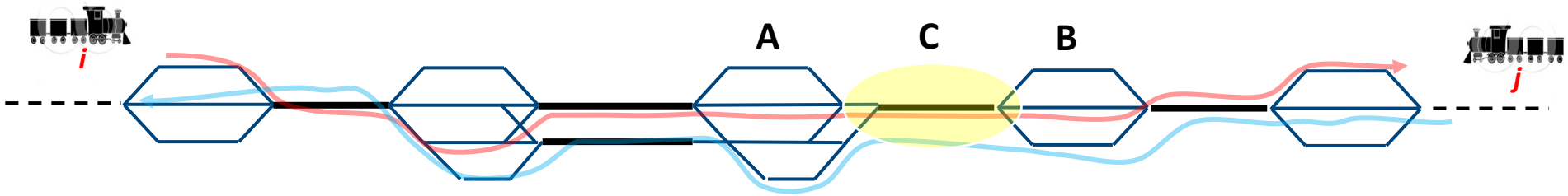
- t_u time train i enters resource r $(u = (i,r))$

SINTEF

The route and competing trains



- Successive movements: $t_v \geq t_u + l_{uv}$ *Simple precedence*

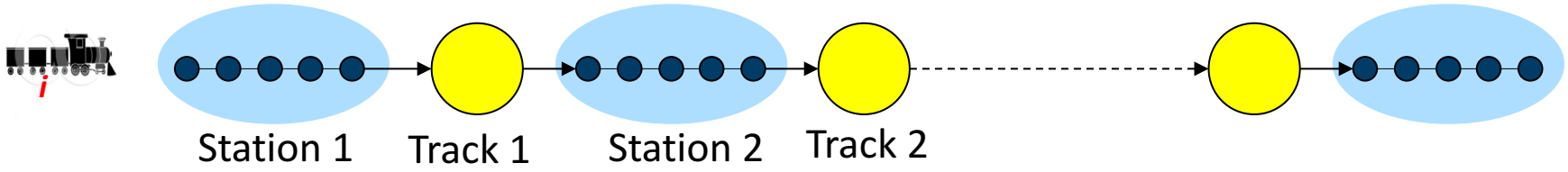


- Distinct trains, incompatible or non-sharable resources:

$t_u - t_w \geq l_{wu} \bigvee t_z - t_v \geq l_{zv}$ *Disjunctive precedence*

SINTEF

A Big-M formulation



$$\min c(t_1)$$

$$\begin{bmatrix} At_1 & \\ 0 & Dt_2 \end{bmatrix} \leq b - My_1 \quad \text{scheduling on the line}$$

$$\leq d - My_2 \quad \text{scheduling in stations}$$

$$\ldots \leq \ldots \quad \text{routing in stations}$$

$$y \in \{0,1\}^n,\ t \in \mathbb{R}^m,$$

Disjunctions are modeled with binary variables and big-M constraints

Problem: large instances, weak formulation

Benders' Decomposition

$\min c(t_1)$

$At_1 \quad \leq b - My_1$ scheduling on tracks

MASTER

The Line Dispatching problem (each station shrinks to a single node)

Find a schedule *t* minimizing c(t) so that trains only meet in stations.

Output: arrival and departure times in stations (timetable!)

$Dt_2 \quad \leq d - My_2$ scheduling in stations

$\ldots \leq \ldots$ routing in stations

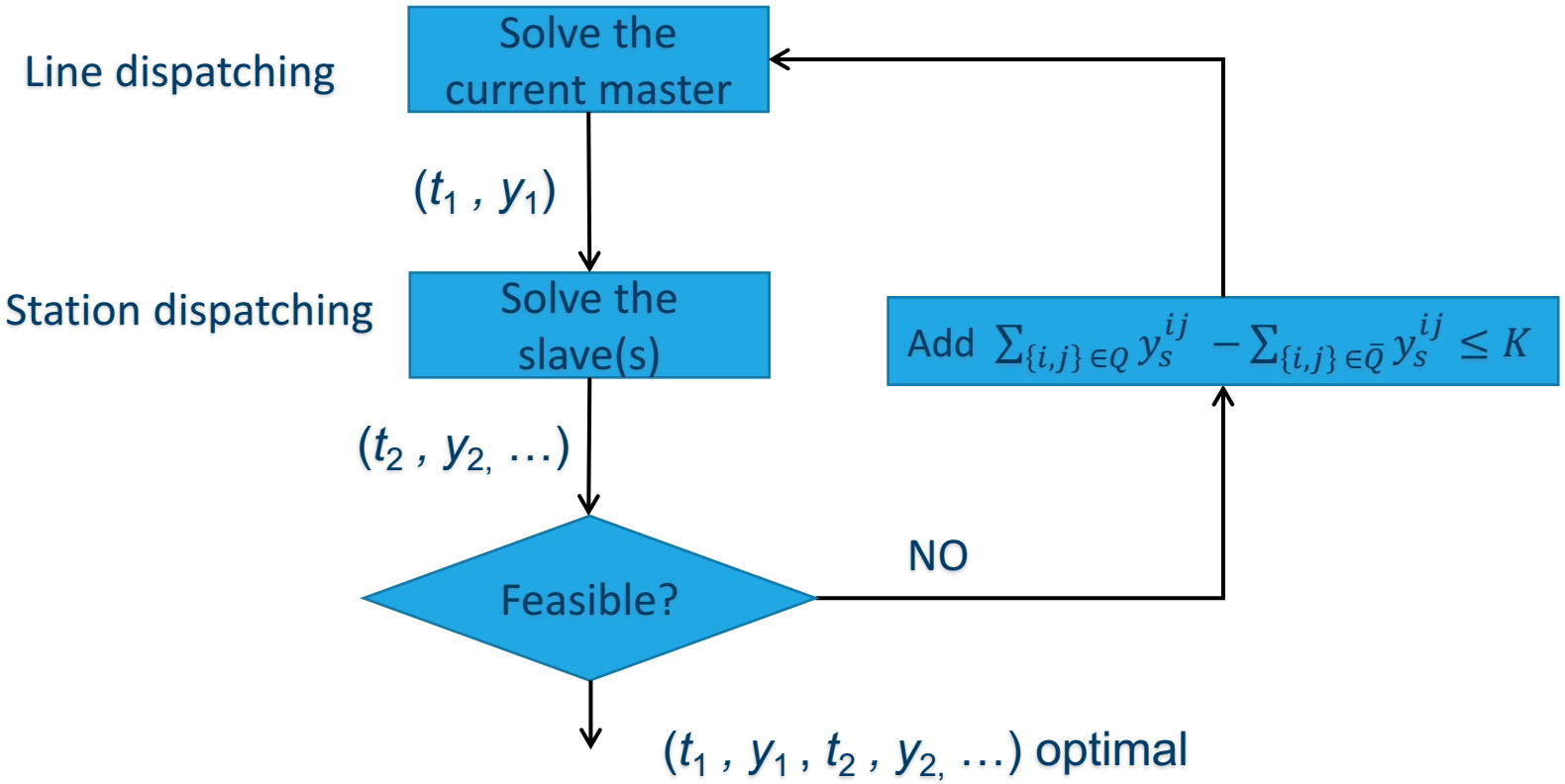
SLAVE(s)

Station Dispatching problem (feasibility)*: Given* a timetable for trains in a station.

Find routes and a conflict-free schedule, or prove problem not feasible.

SINTEF

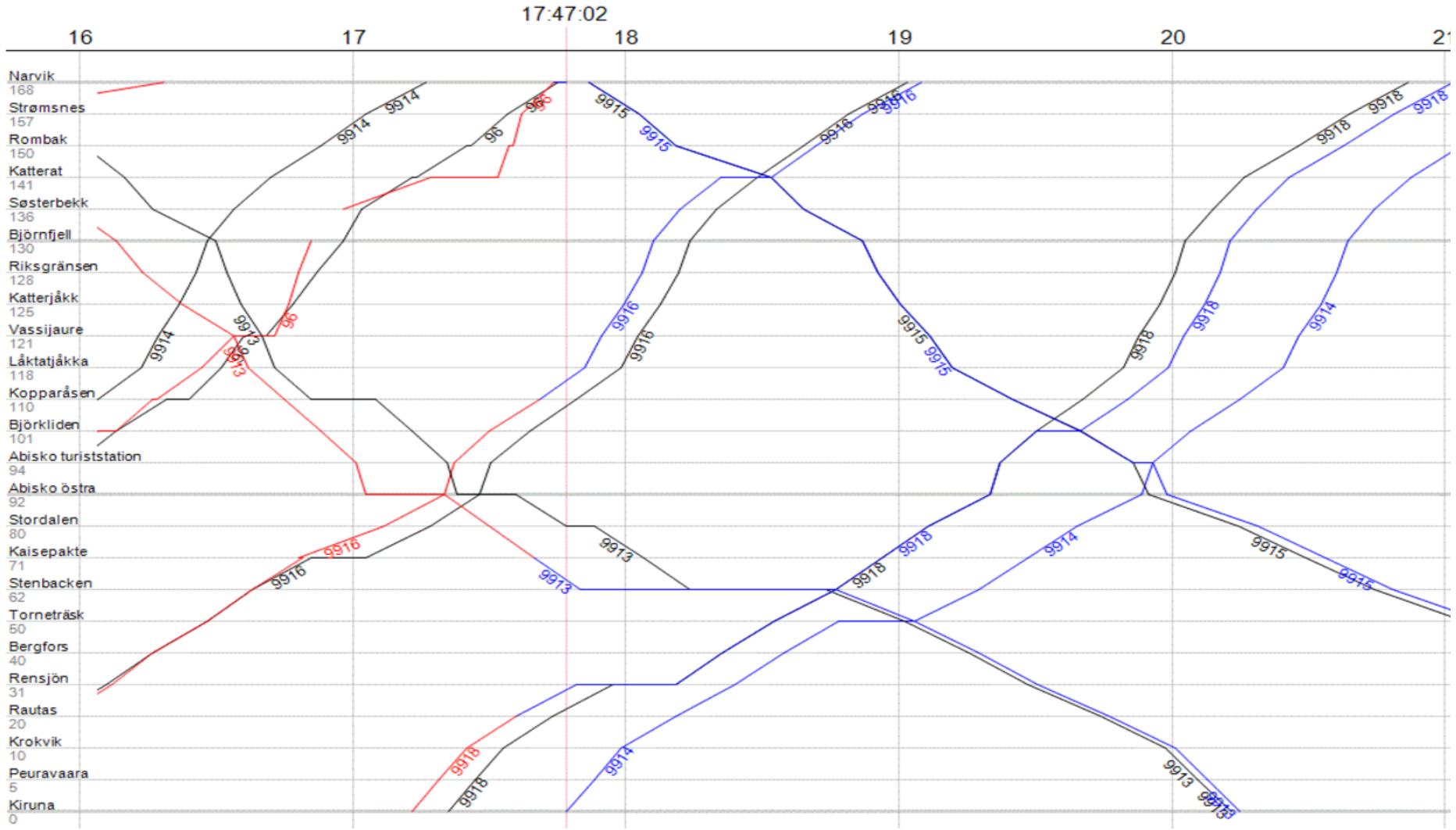
Solving the Train Dispatching problem



Status

- Iron ore line modelled
- Tool deployed online
- Real time data from Trafikverket and BaneNor
- In use by dispatchers in Narvik from February

Demo


17:47:02
16
17
18
19
20
Narvik
168
Strømsnes
157
Rombak
150
Katterat
141
Søsterbekk
136
Björnfjell
130
Riksgränsen
128
Katterjåkk
125
Vassijaure
121
Låktatjåkka
118
Kopparåsen
110
Björkliden
101
Abisko turiststation
94
Abisko östra
92
Stordalen
80
Kaisepakte
71
Stenbacken
62
Torneträsk
50
Bergfors
40
Rensjön
31
Rautas
20
Krokvik
10
Peuravaara
5
Kiruna
0

Thank you for attending!
-questions?

Technology for a better society