Operative Traffic Management for Energy-Efficient Train Operation

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(Joint Work with Tilo Schumann)

Motivation

Starting point: Many train operators have installed driver advisory systems (DAS) into their rolling stock ⇝ energy savings.

Drawback: DAS do not take conflicts with other trains into account.

Next generation: Connected DAS. Examples:

- CATO (Iron ore line from Kiruna to Narvik)
- ADL (Switzerland)

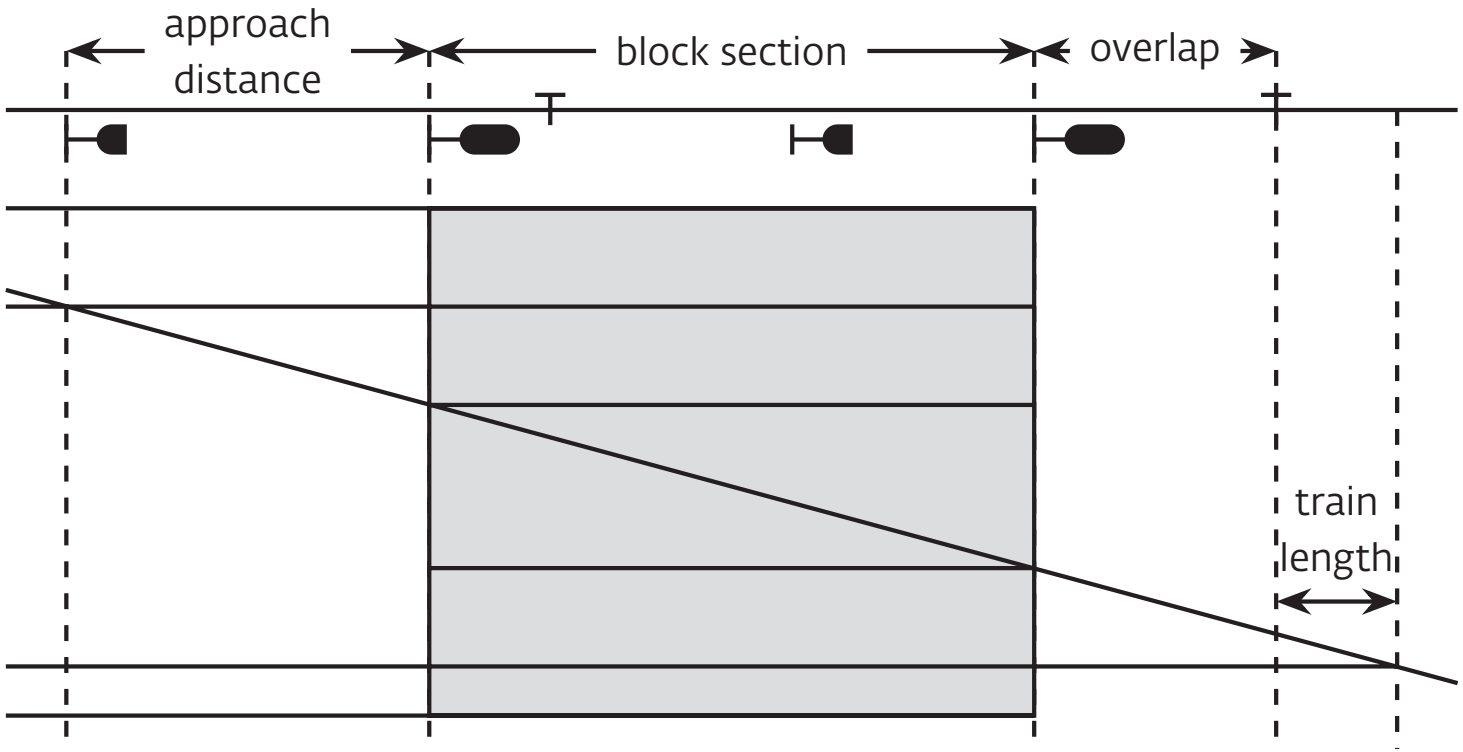
These are monolithic solutions where DAS and central unit have been designed together.

Our Contribution: Open system that can work with DAS from different vendors.

Blocking Time Windows

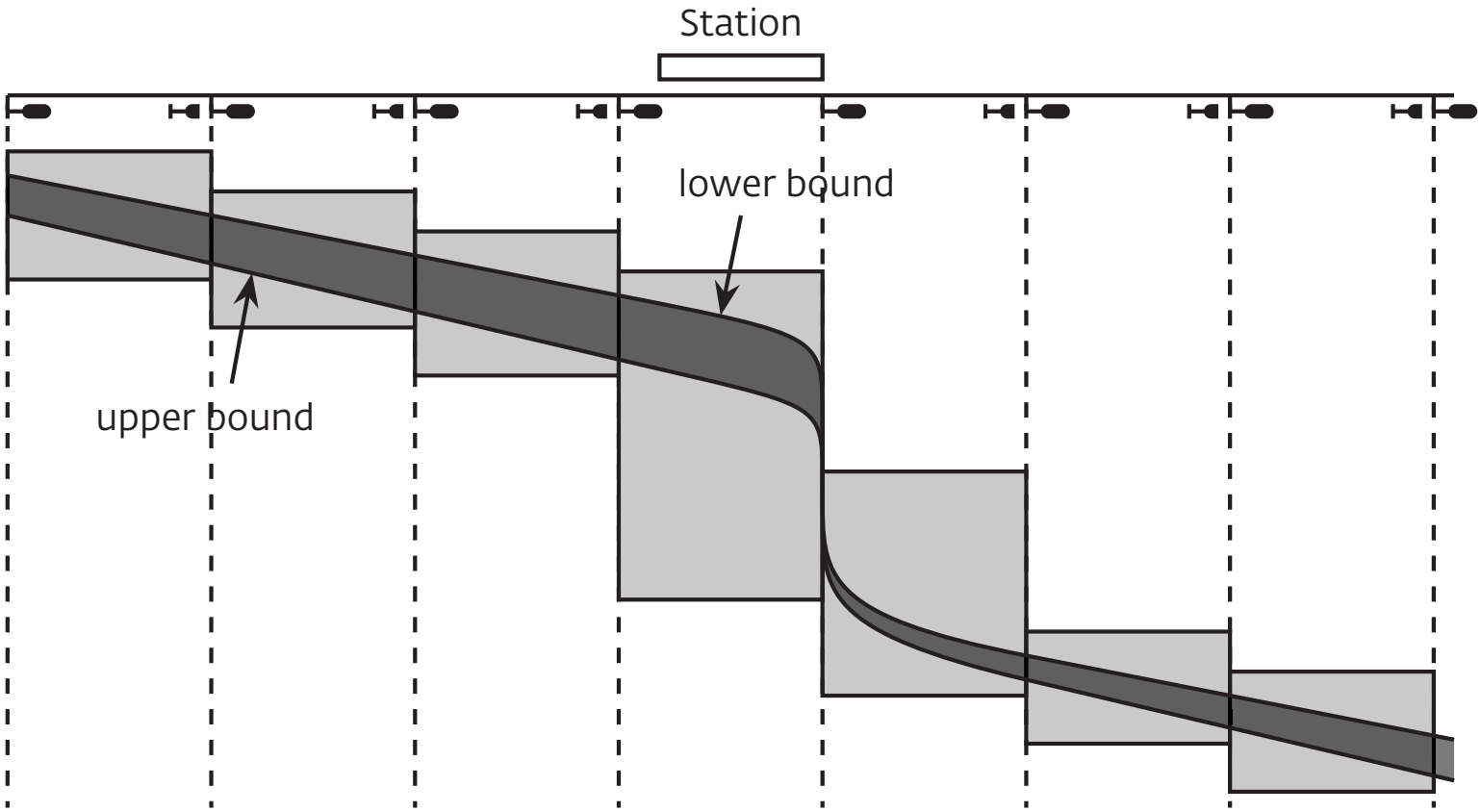
Assumption: Fixed-length block system with trackside signals.

Blocking time window describes the period of time a block is exclusively allocated by a train.



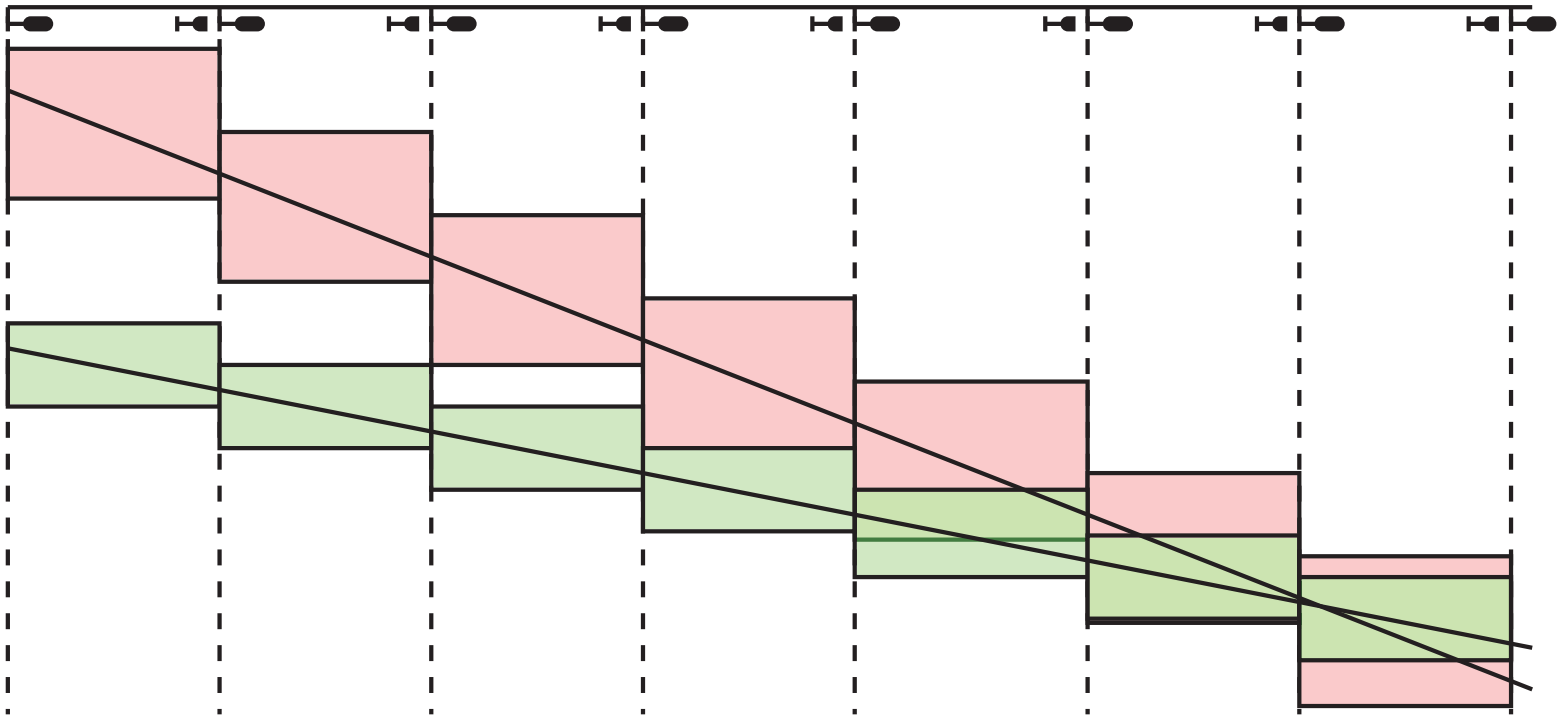
Blocking Time Window Approximation

Problem: Exact trajectory not known in advance due to differences in driving syle, variances in dwell time, . . . ⇝ *Approximation*.



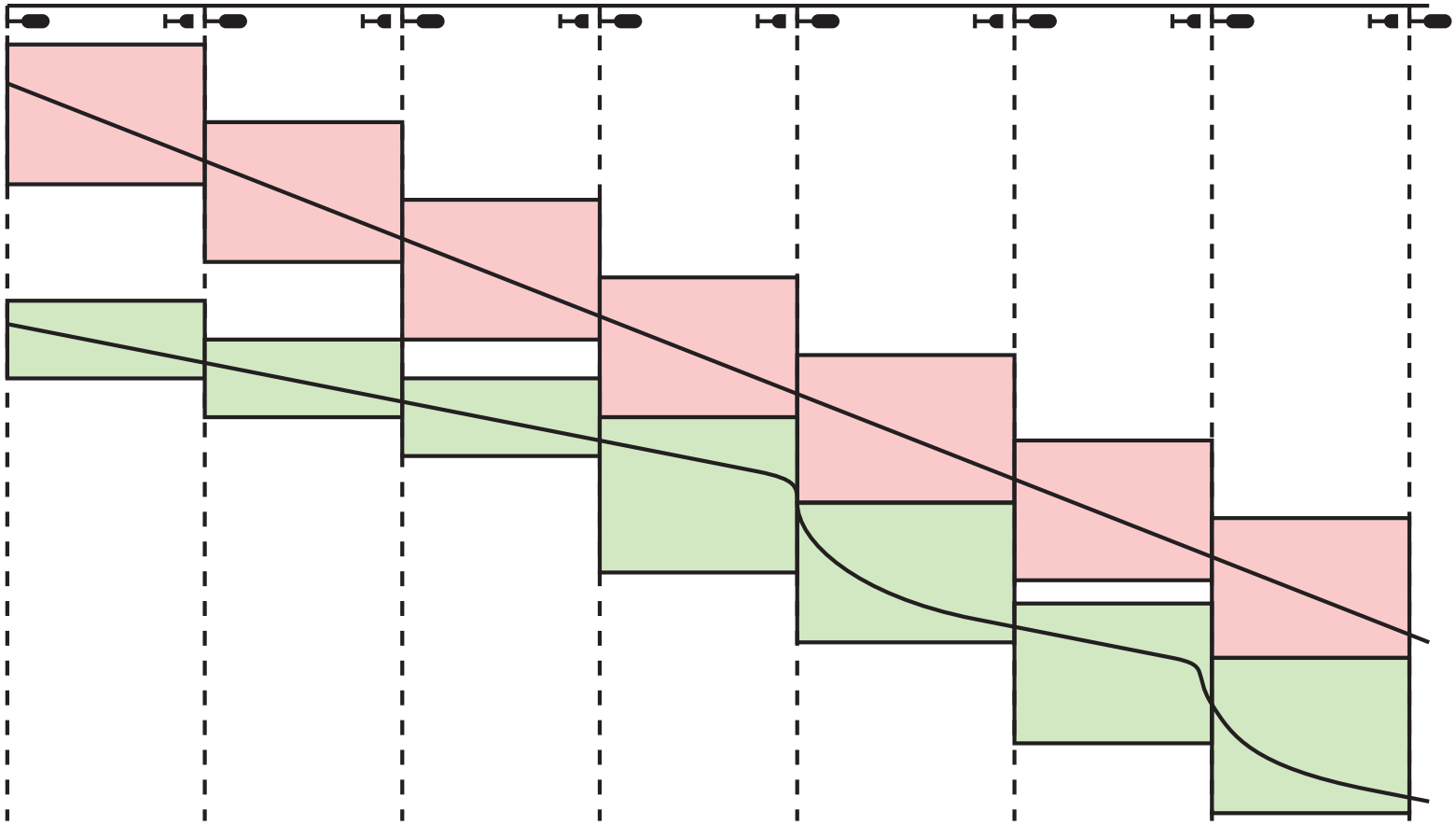
Conflicts

A **conflict** occurs if the blocking windows of two trains overlap in at least one block section (e.g. due to a primary delay).



Conflict Resolution

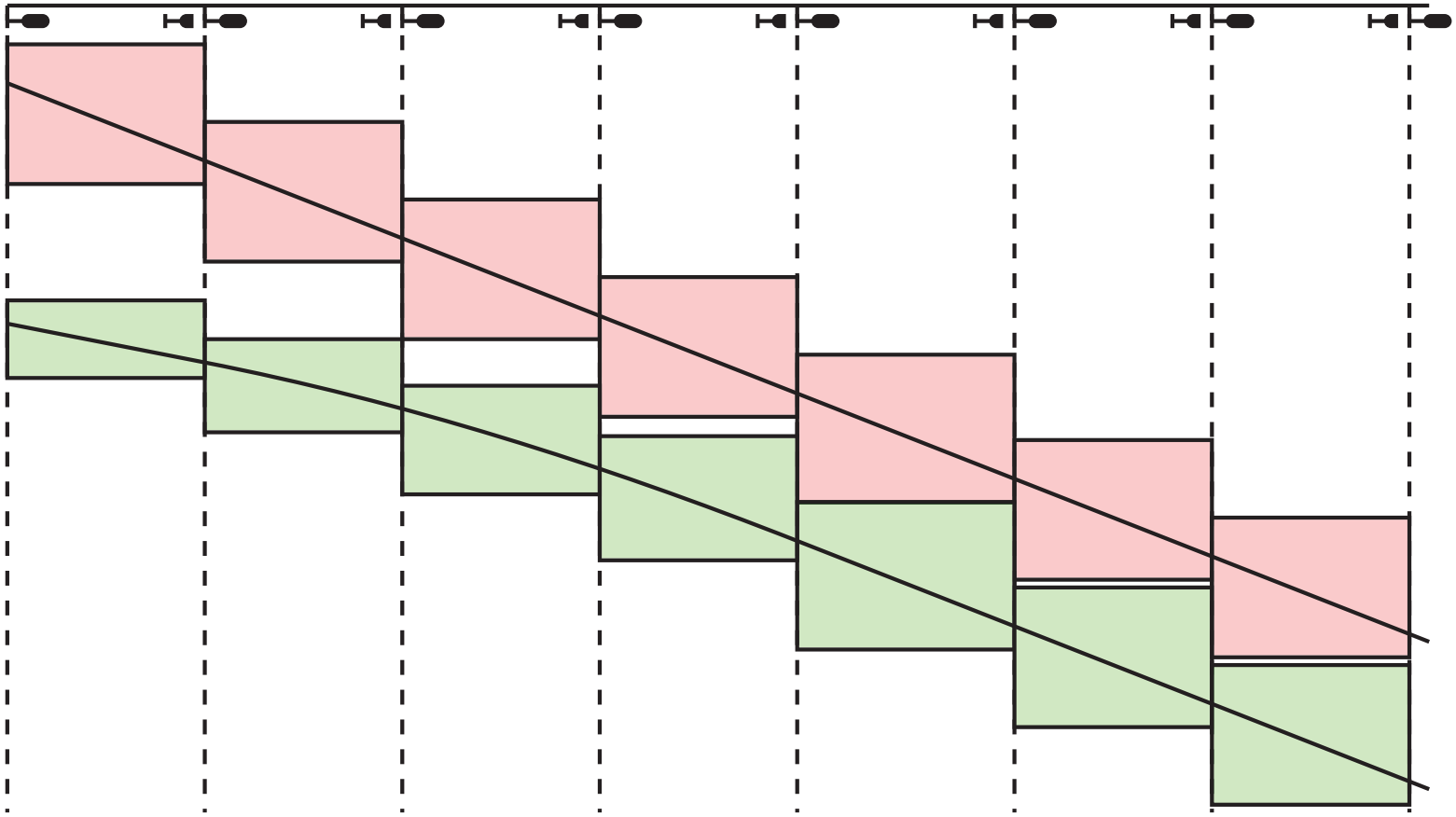
Signalling system resolves conflicts “by force”.



Problem: High energy consumption and larger blocking windows.

Conflict Resolution (Cont.)

Better: Identify and resolve conflicts ahead of time.



Requirement: Protocol for communication with trains.

The EETROP Protocol

EETROP: Simple XML protocol for exchanging train data (RailEnergy).

```
<positionReportMessage>
  <systemTime>2013-03-14T09:13:51.0</systemTime>
  <trainIdentity>1234</trainIdentity>
  <position>
    <trainPosition>
      <trackRef>tr1a</trackRef>
      <positionOnTrack>200.0</positionOnTrack>
    </trainPosition>
    <trainSpeed>29.7</trainSpeed>
  </position>
</positionReportMessage>
```

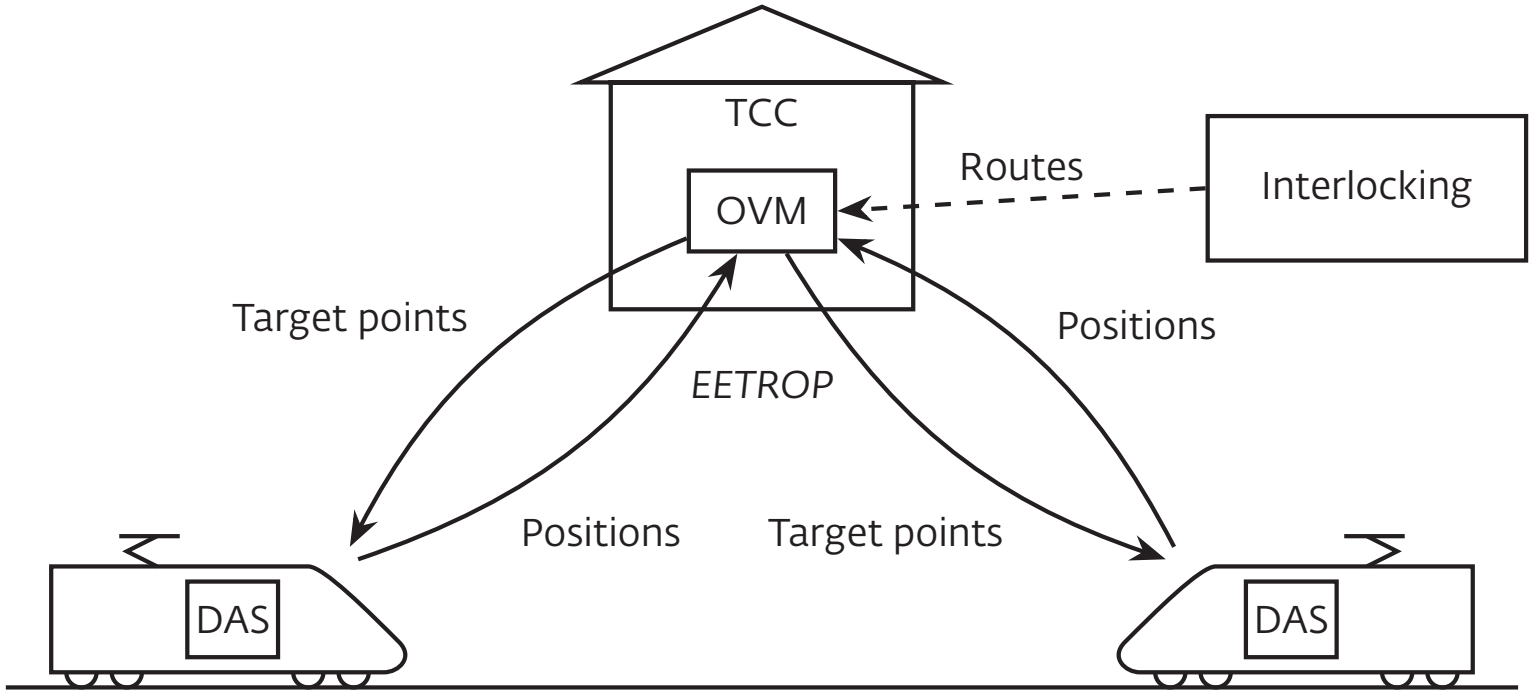
The EETROP Protocol (Cont.)

EETROP: Simple XML protocol for exchanging train data (RailEnergy).

```
<partialTarget>
  <trainPosition>
    <trackRef>tr2b</trackRef>
    <positionOnTrack>1200.0</positionOnTrack>
  </trainPosition>
  <time>10:52:06.597</time>
  <speed>10.0</speed>
  <earliestLatest>EARLIEST</earliestLatest>
  <slowerFaster>FASTER</slowerFaster>
</partialTarget>
```

Target points specifiy earliest or latest arrival at a given waypoint.

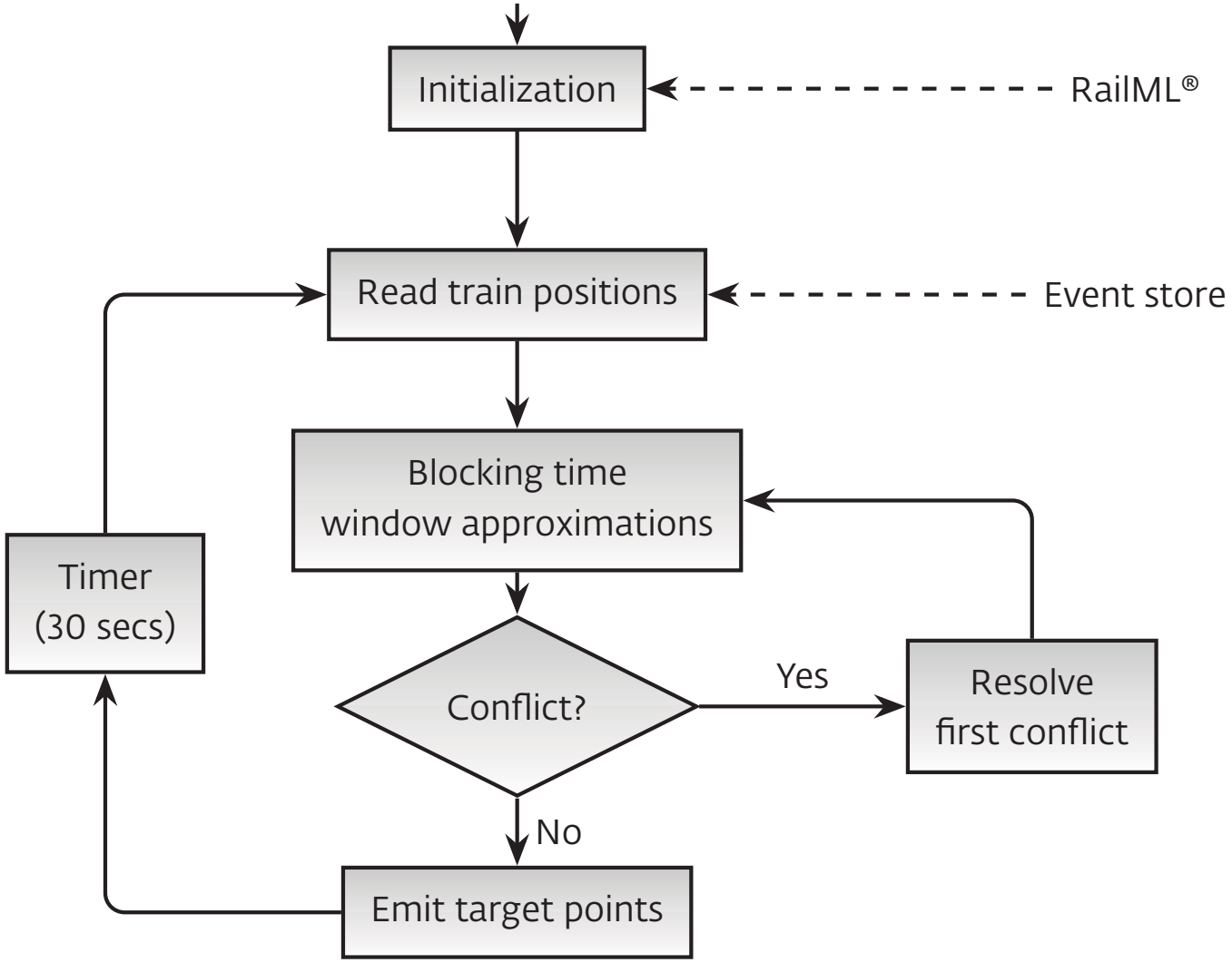
System architecture



Note: (Energy-optimal) Trajectory optimization performed by DAS.

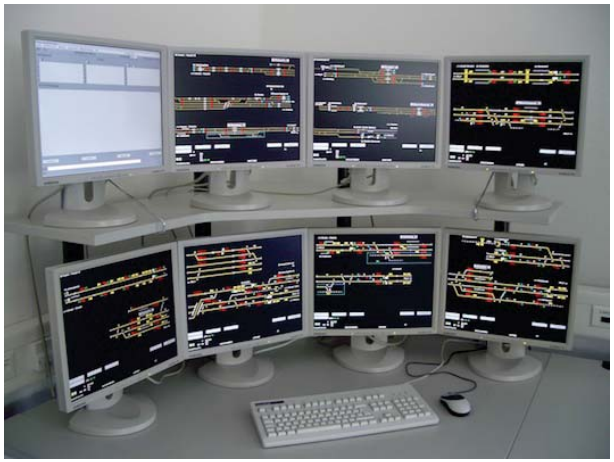
Note: Any DAS may be used as long as it supports EETROP.

Implementation (Closed Loop)



Demonstration

Demonstration: In DLR's simulation environment RailSiTe®.

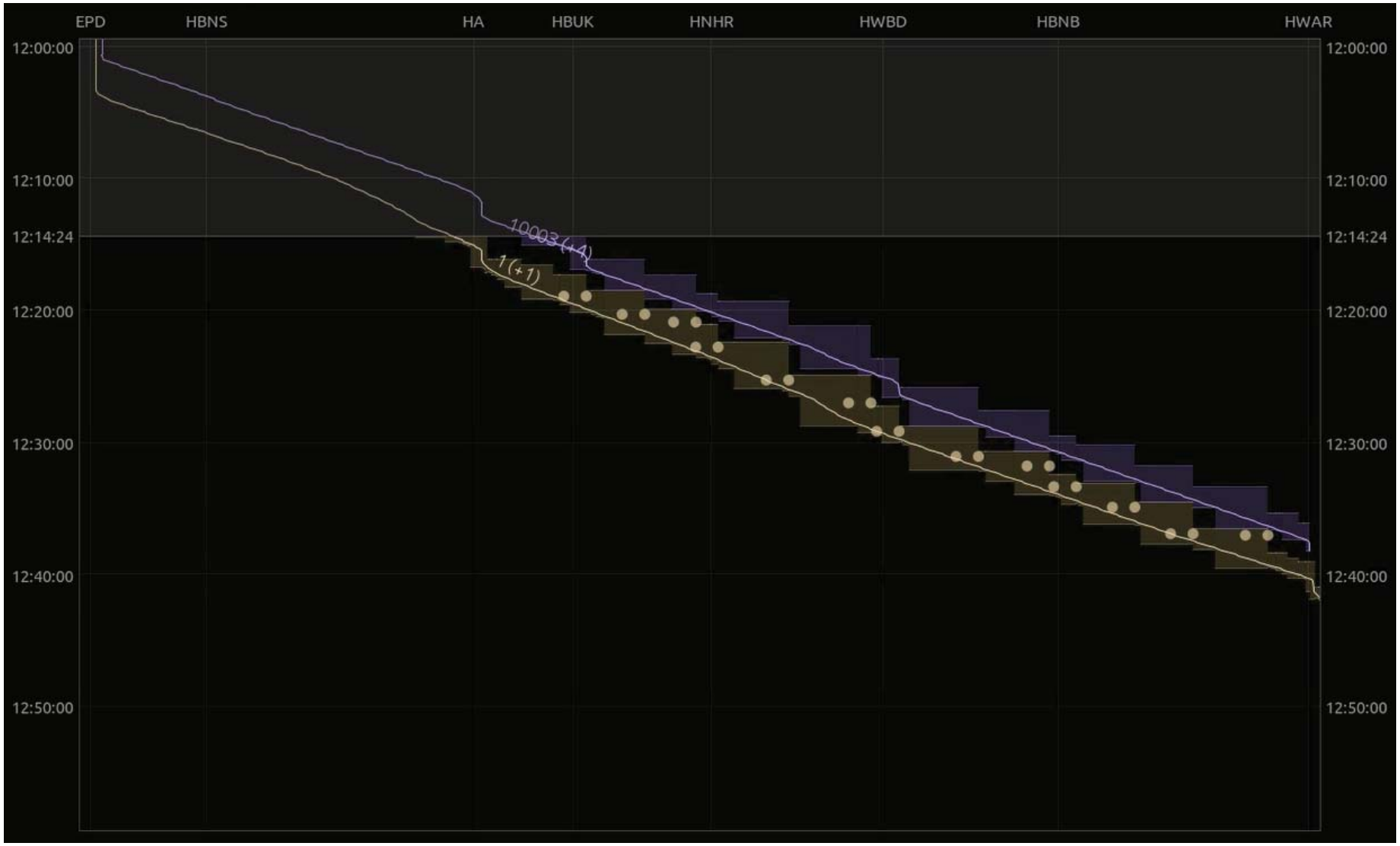


Scenario: Slow regional train (automatically controlled) followed by InterCity train (manually driven).

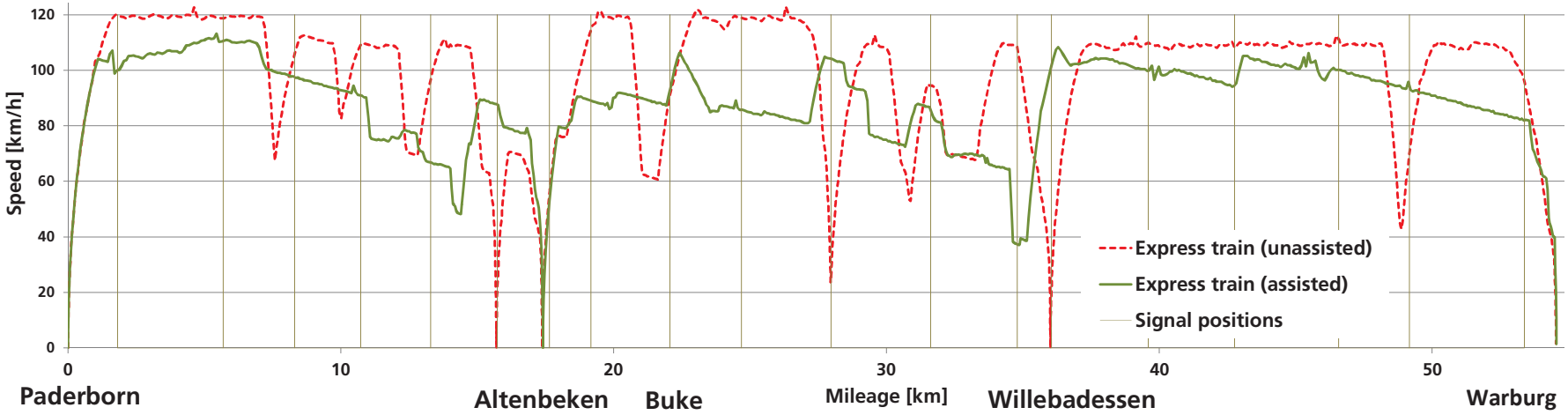
Line: Electrified main line from Paderborn to Warburg in Germany.

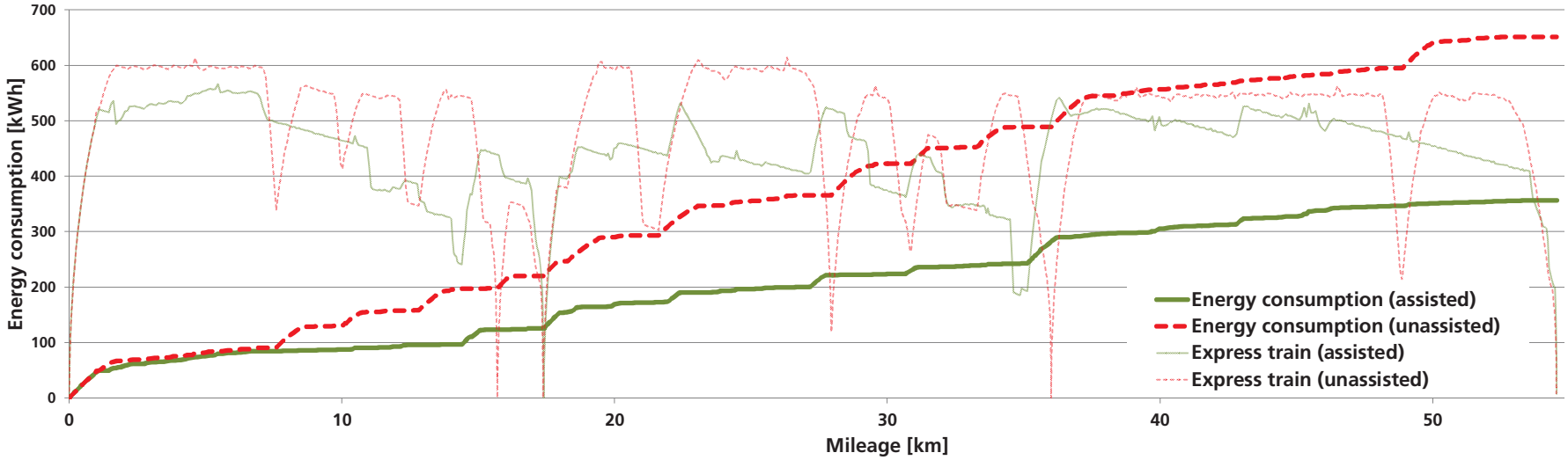
DAS: provided by TU Dresden and Interautomation.

Screenshot


EPD
HBNS
HA
HBUK
HNHR
HWBD
HBNB
HWAR
12:00:00
12:10:00
12:14:24
12:20:00
12:30:00
12:40:00
12:50:00
10003 (+4)
1 (+1)

Results


Speed [km/h]
120
100
80
60
40
20
0
0
10
20
30
40
50
Mileage [km]
Paderborn
Altenbeken
Buke
Willebadessen
Warburg
Express train (unassisted)
Express train (assisted)
Signal positions


Energy consumption [kWh]
700
600
500
400
300
200
100
0
0
10
20
30
40
50
Mileage [km]
Energy consumption (assisted)
Energy consumption (unassisted)
Express train (assisted)
Express train (unassisted)

Conclusions

Results:

- Open system for network-wide optimzation.
- Potential for massive energy savings.

Challenges:

- Study influence on line capacity.
- Incorporate dispatching decisions.
- Separation of infrastructure and train operation.