Operative Traffic Management for Energy-Efficient Train Operation

Michael Ummels

DLR — German Aerospace Center
michael.ummels@dlr.de

(Joint Work with Tilo Schumann)
Motivation

Starting point: Many train operators have installed driver advisory systems (DAS) into their rolling stock → energy savings.
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.
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)
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.
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 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 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 style, variances in dwell time, ... \(\sim\) *Approximation.*
Blocking Time Window Approximation

**Problem:** Exact trajectory not known in advance due to differences in driving style, 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).
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).
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”.
Conflict resolution

Signalling system resolves conflicts “by force”.

[Diagram showing signalling system resolving conflicts]
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.
Conflict Resolution (Cont.)

Better: Identify and resolve conflicts ahead of time.
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).
The EETROP Protocol

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

```xml
<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).
The EETROP Protocol (Cont.)

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

```xml
<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 specify earliest or latest arrival at a given waypoint.
System architecture
System architecture

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

1. Initialization
2. Read train positions
3. Blocking time window approximations
4. Conflict?
   - Yes: Resolve first conflict
   - No: Emit target points

Event store
RailML®
Timer (30 secs)
Demonstration

**Demonstration:** In DLR’s simulation environment RailSiTe®.
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.
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.
Results

![Graph showing speed and mileage for different train types and signal positions.]

- **Express train (unassisted)**
- **Express train (assisted)**
- **Signal positions**

Mileage [km]

- Paderborn
- Altenbeken
- Buke
- Willebadessen
- Warburg

Speed [km/h]
Results

Graph showing speed and mileage for an express train (unassisted) and an express train (assisted), with signal positions indicated along the route from Paderborn to Warburg.

Graph showing energy consumption for an express train (unassisted) and an express train (assisted), with the total energy consumption increasing along the route from Paderborn to Warburg.
Conclusions

Results:

- Open system for network-wide optimization.
- Potential for massive energy savings.
Conclusions

Results:

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

Challenges:

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