Building a KG for the European Railway Agency: The story

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International Workshop On Semantics And The Web For Transport
SEMANTiCS Conference
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GHENT UNIVERSITY

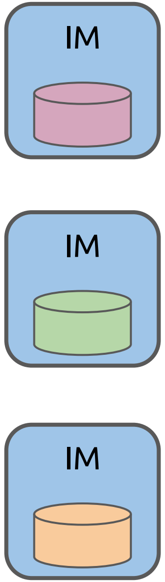
EUROPEAN UNION AGENCY FOR RAILWAYS

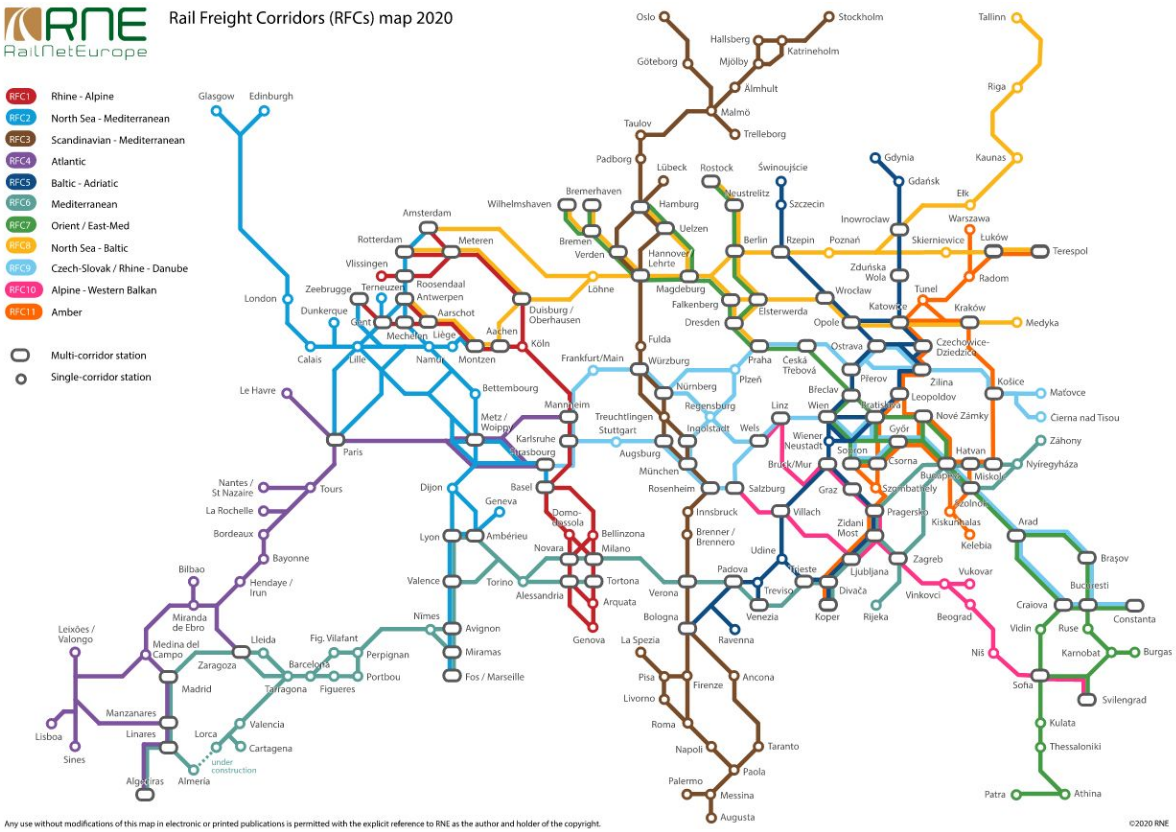
imec

Agenda

- Intro context and use case motivation
    - Who are ERA
    - Data sources
    - Use case
- Data exploration and modeling
    - Ontology definition (v1, v2 and beyond)
- Data Mapping
    - (YARR)RML mapping architecture
    - Challenging mappings (Conditionals, gradient profile)
- Data integration
    - Integration at mapping time vs integration at Querying time
    - Accurate routing (railML)
    - OSM (geo-shapes, others)
    - Challenging mappings/post-processing (interlinking, CONSTRUCT queries)
- RCC
    - Solving routes (OSRM vs client-side)
    - Compatibility assessment (SHACL-rules?)
    - Compatibility based on meteorological conditions
    -
- Conclusions and next steps
    - Quality assurance
    - IM independent generation (mappings, phase-out of RINF)
    - LDES-based generation
    - Shortest-path querying on KGs (Contraction Hierarchies)

European railway ecosystem





RU

RU

RU

The European Agency for Railways (ERA)

Mission: Moving Europe towards a sustainable and safe railway system without frontiers.

Tasks:

- Promote a **harmonised approach** to railway safety
- Devise the technical and legal **framework** in order to enable **removing technical barriers**, and acting as the system authority for ERTMS and telematics applications
- **Improve accessibility** and use of railway system **information**
- Act as the **European Authority** under the 4th Railway Package issuing vehicle (type) authorisations and single safety certificates, while improving the competitive position of the railway sector.

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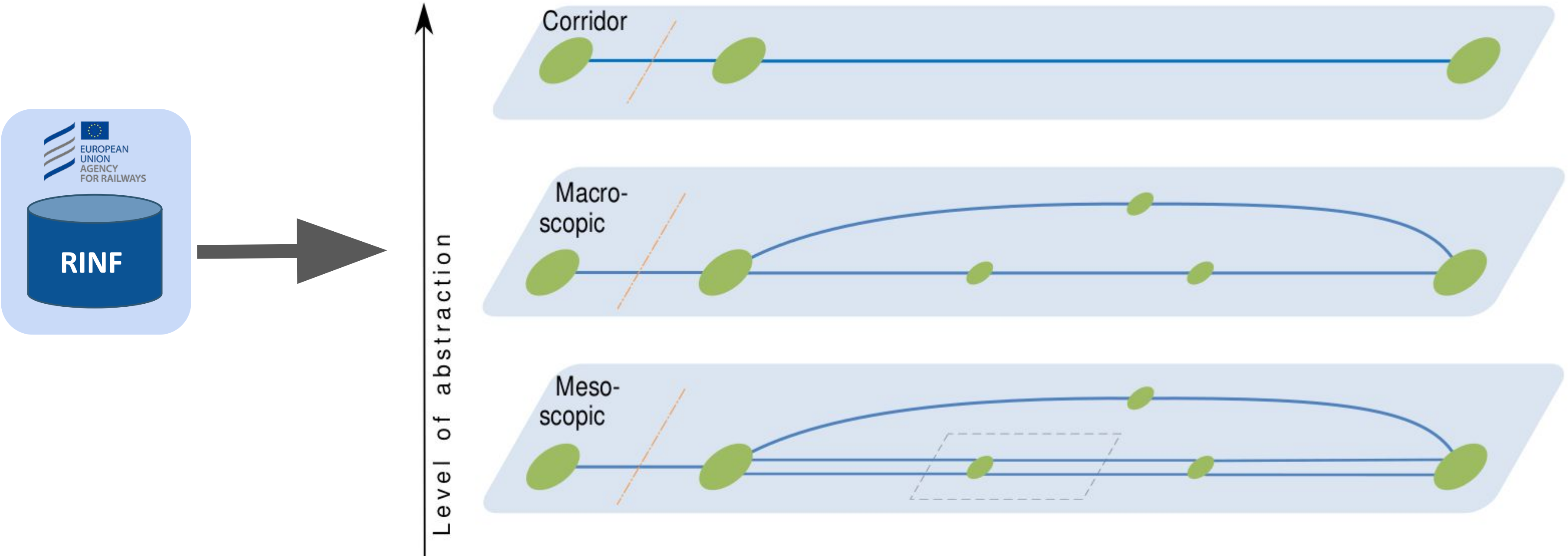
ERA aims on creating interoperability for stakeholders

Register of Infrastructure (RINF)

RINF contains the main features of fixed installations related to the subsystems of **infrastructure**, energy and parts of control-command and signaling



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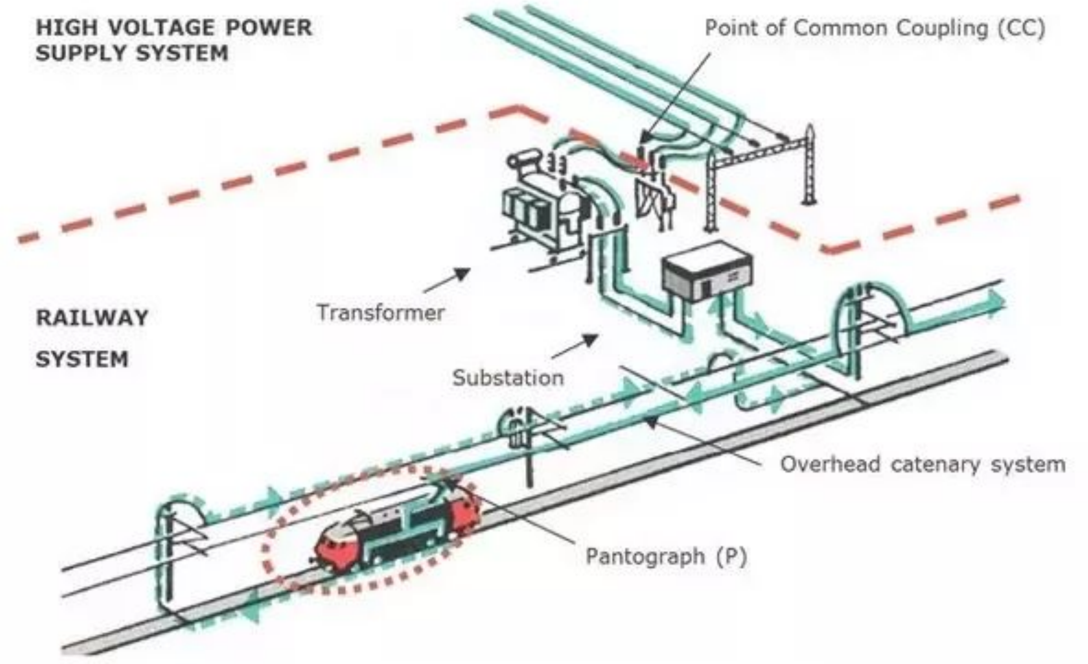
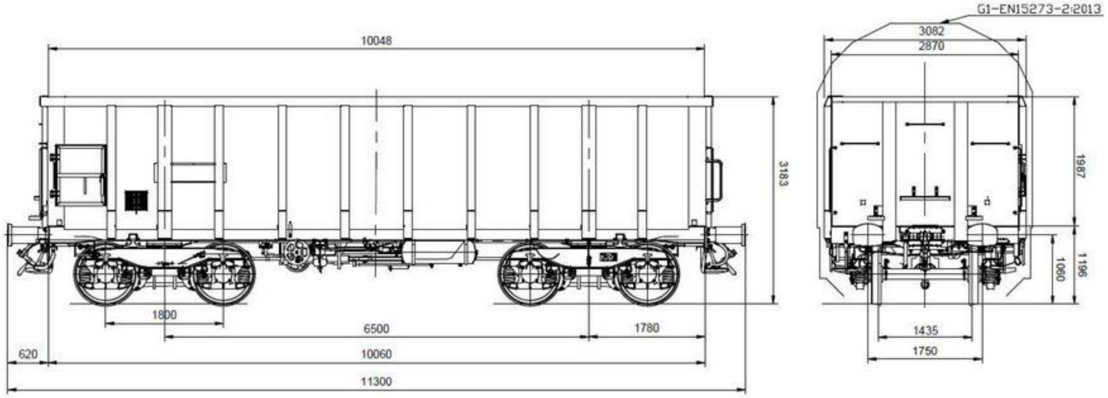
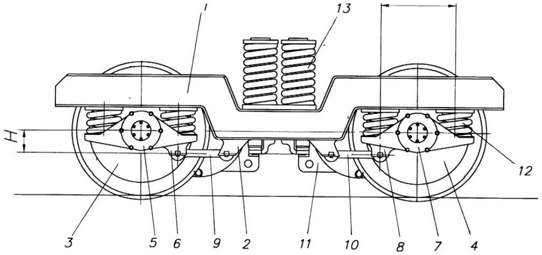


European Register of Authorized Types of Vehicles (ERATV)

ERATV publishes and keeps an up-to-date set of authorized types of vehicles including information that references their technical specifications.





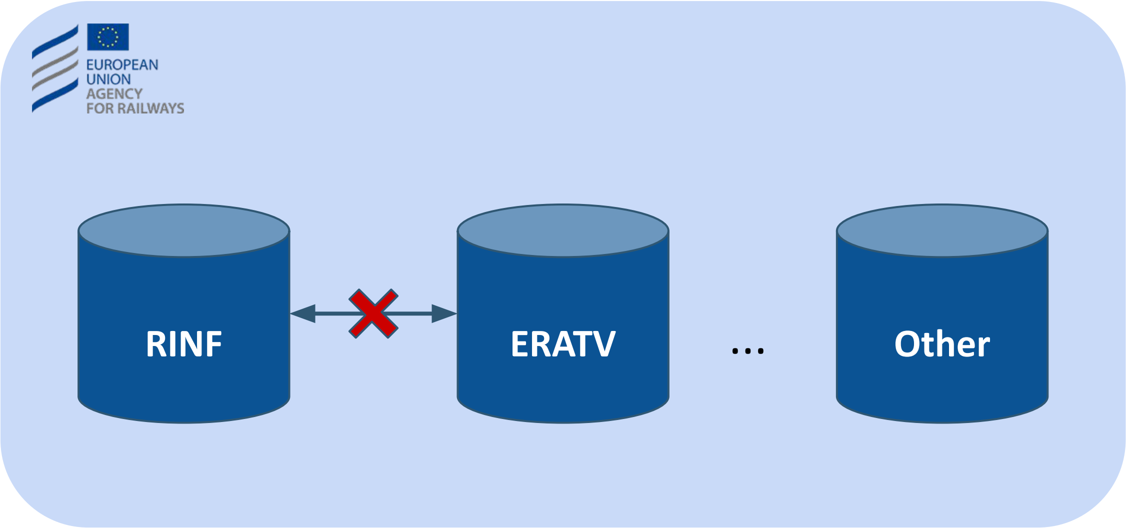
Use case: Route Compatibility Check (RCC)

"Before a railway undertaking uses a vehicle in the area of use specified in its authorisation for placing on the market, it shall check: …(b) that the vehicle is compatible with the route on the basis of the infrastructure register…"

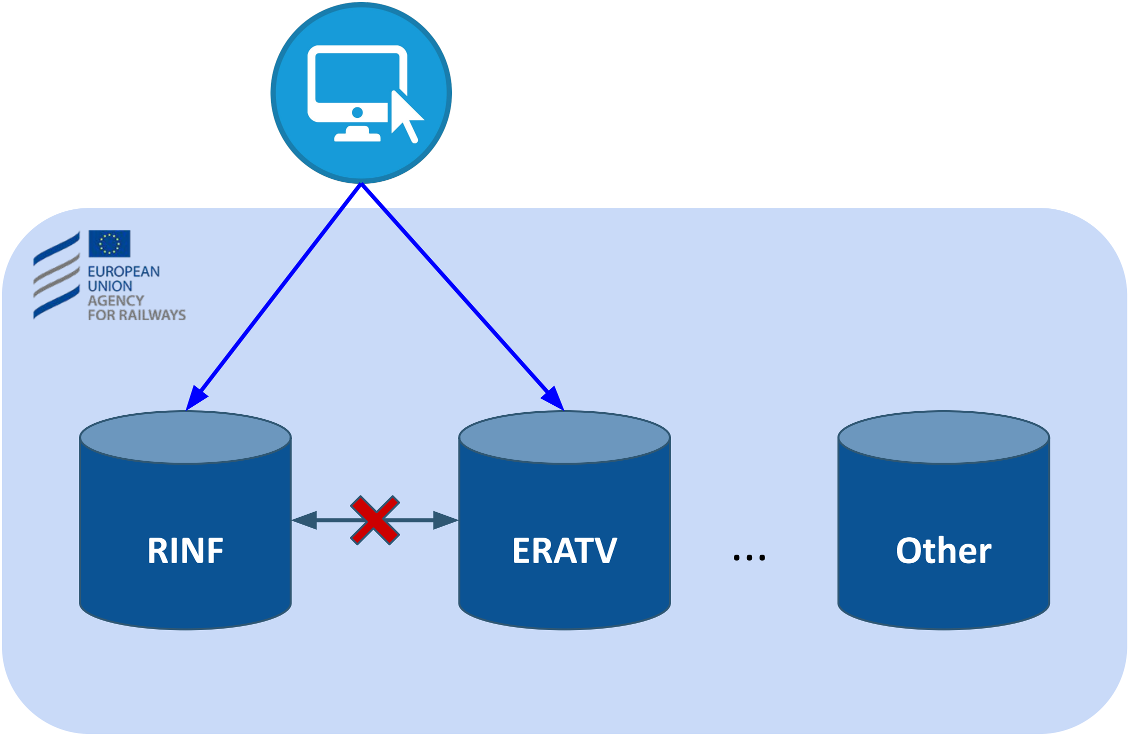
European regulation 2016/797

E.g.: What is the shortest **compatible route** with **vehicle C30-M** from Paris to Amsterdam?

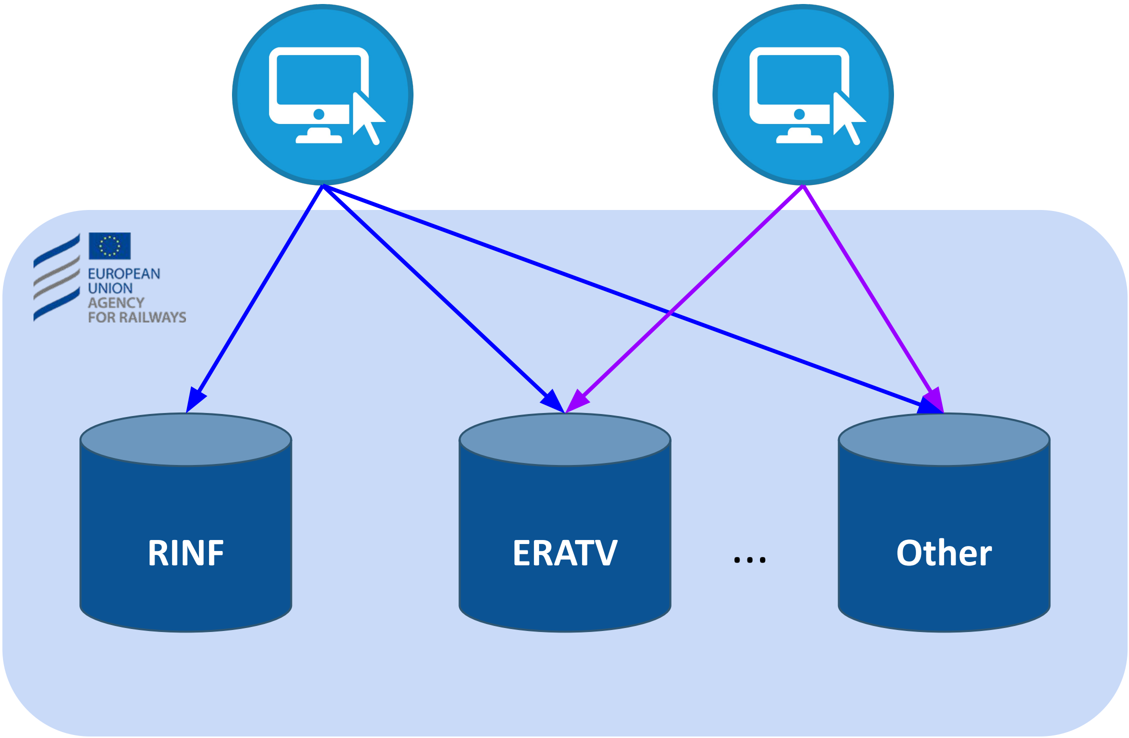
Data silos difficult interoperability



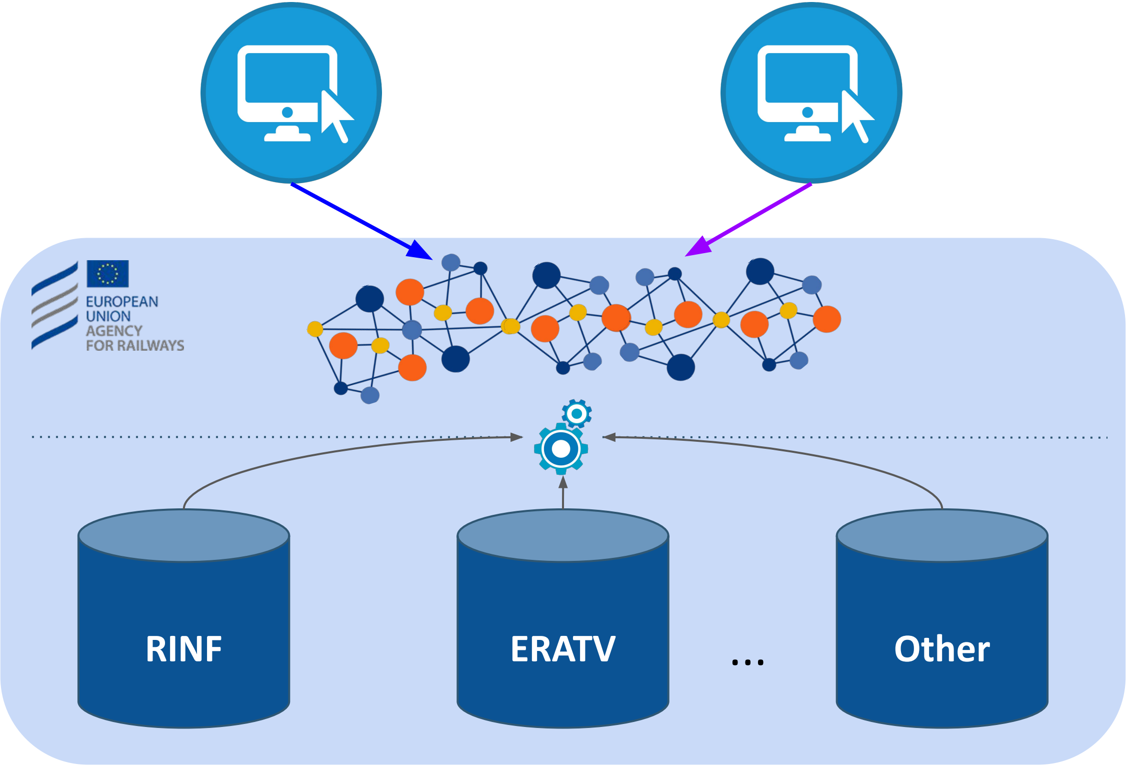
Data silos difficult interoperability and **force application-centric solutions** for data integration



Data integration hidden in application code is **expensive to maintain and reuse**



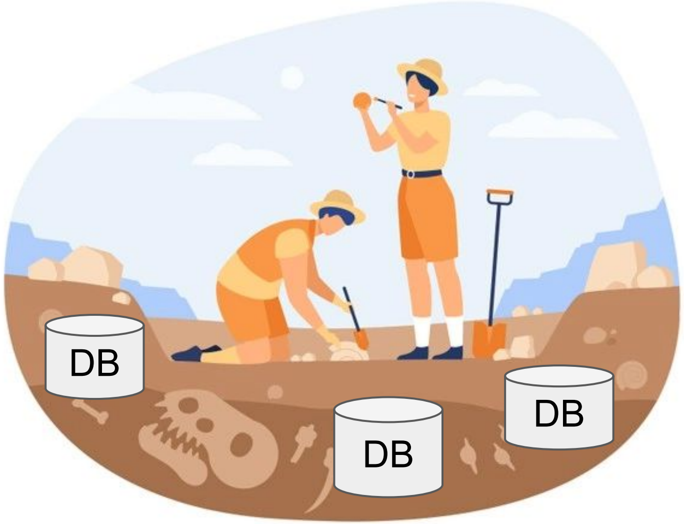
A **semantic layer** for Knowledge Graph-based interoperability that enables data-centric solutions



ACT I: Data exploration and modelling

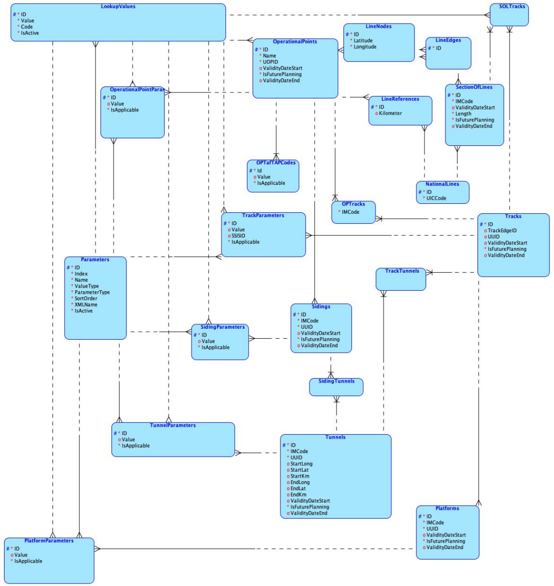
We started with some *data archeology* …

The documentation

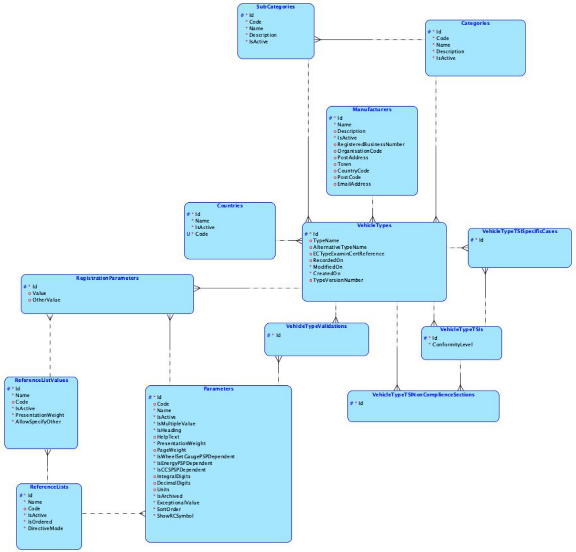


Entity-relation diagrams

And we went from this…

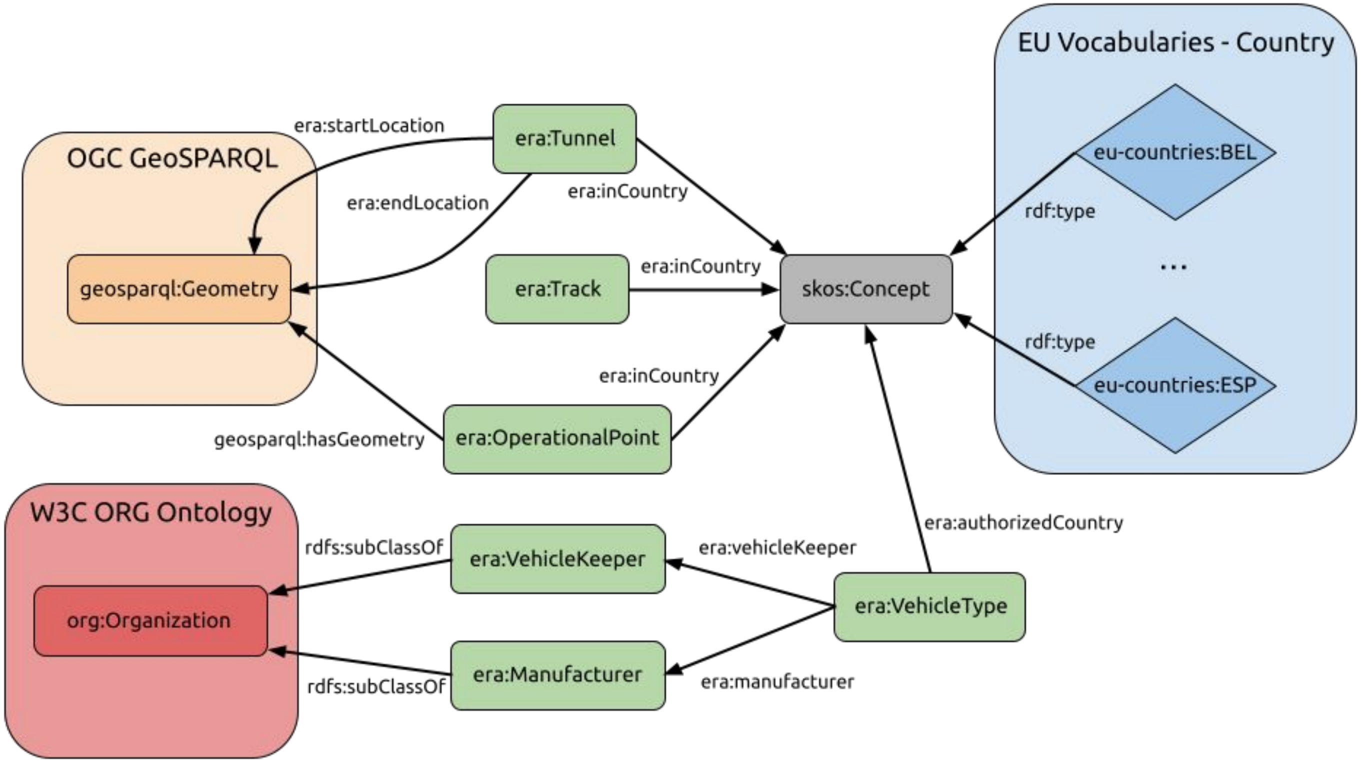


Main tables in RINF

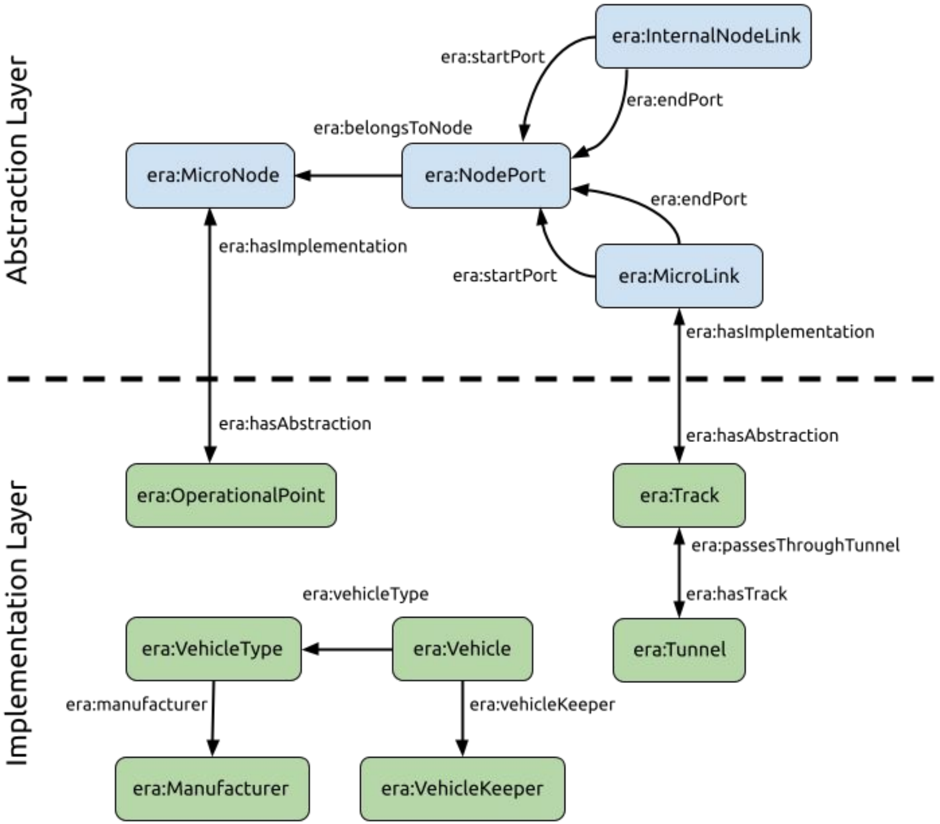


Main tables in ERATV

To this: The ERA Vocabulary v1

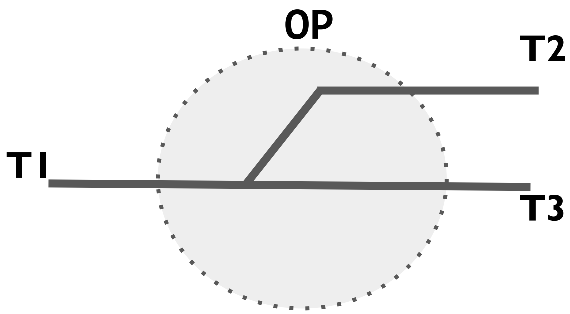


Topology model of the ERA Vocabulary v1

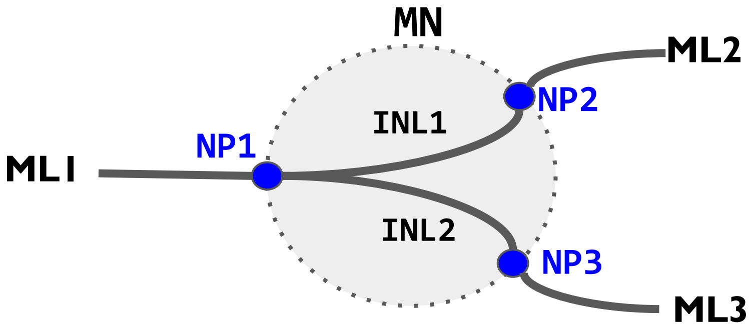


Topology model of the ERA Vocabulary v1

Real-world schematic scenario



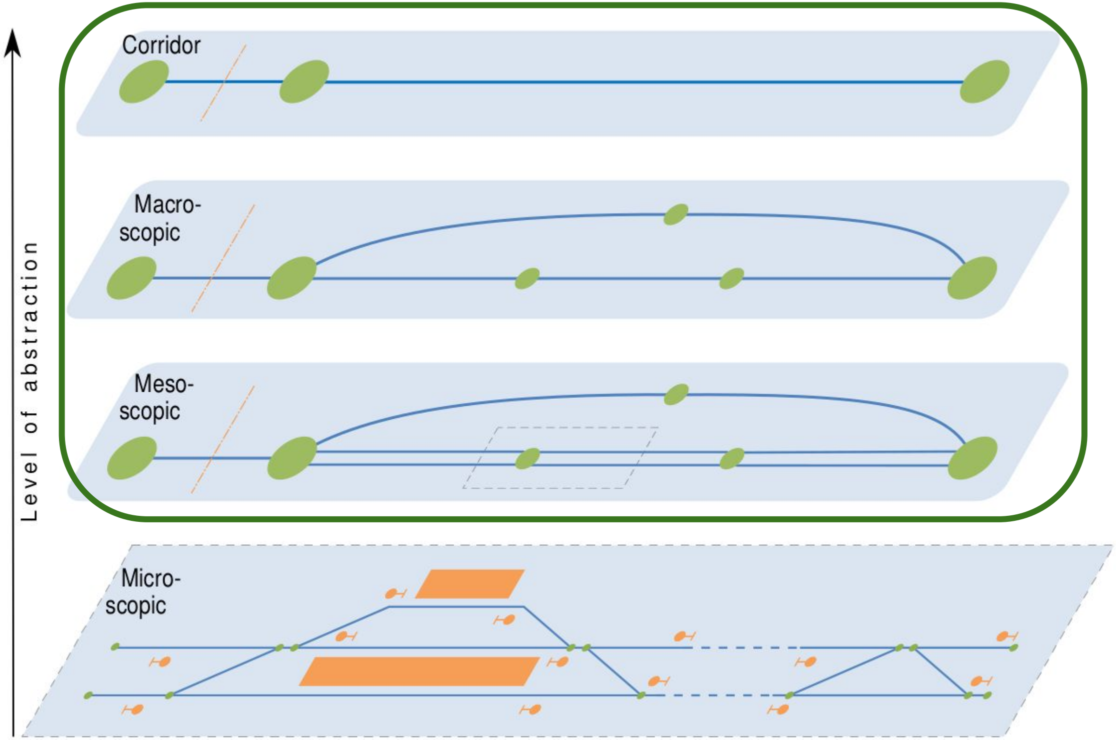
Modelled in the ERA Vocabulary



ERA Vocabulary:

MN: era:MicroNode
MLx: era:MicroLink
NPx: era:NodePort
INLx: era:InternalNodeLink

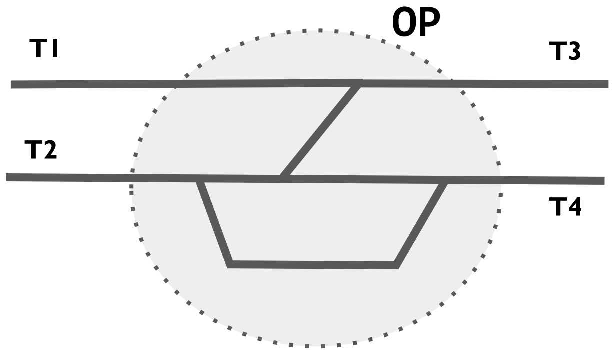
RINF's data model does not provide sufficient level of detail for topological description



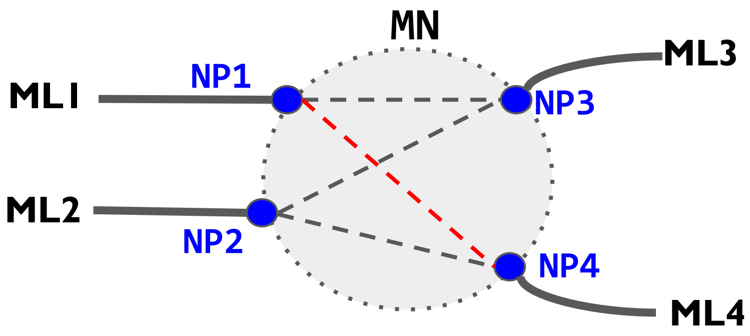
RINF reaches this level of detail

Full connectivity assumption → leads to incorrect topology

Real-world schematic scenario



Modelled in the ERA Vocabulary



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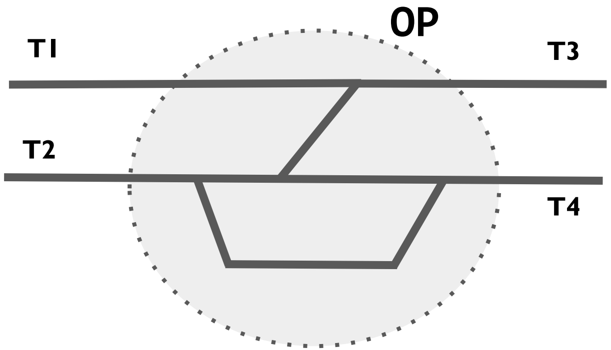
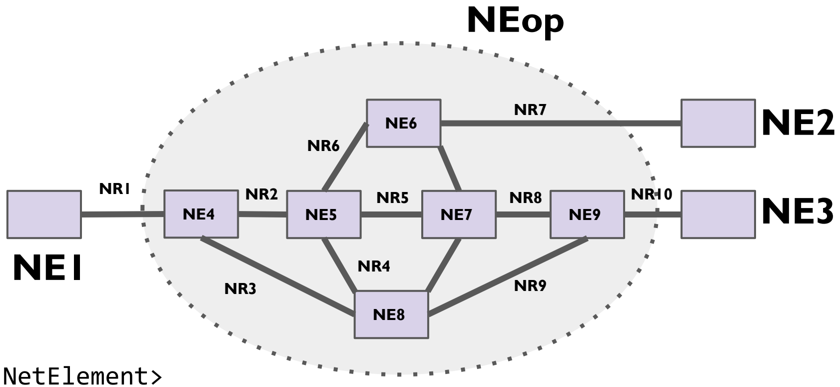
RailTopoModel standard-based modelling (aka connexity graph*)

Real-world schematic scenario



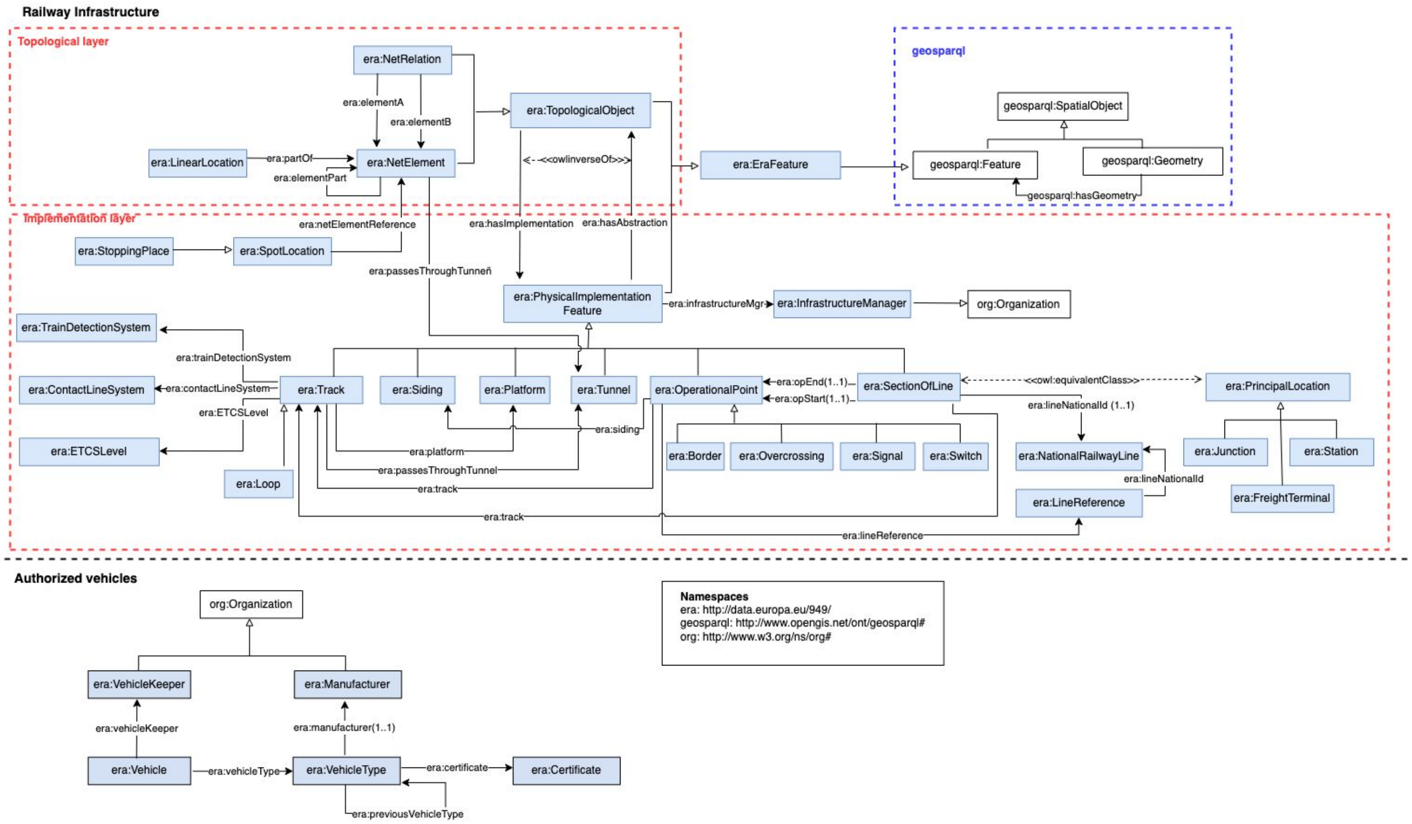
Modelled with RailTopoModel



NEx: <NetElement>
NRx: <NetRelation>

* Gély et al., A multi scalable model based on a connexity graph representation, 2010

Enter the ERA Vocabulary v2



Enter the ERA Vocabulary v2

Ontology Specification

EUROPEAN UNION AGENCY FOR RAILWAYS

ERA vocabulary. Version 2.5.2

This version:
https://data-interop.era.europa.eu/era-vocabulary/

Version:
v2.5.2 (released on 2022-09-05)

Publisher:
European Union Agency for Railways

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Cite as:
European Union Agency for Railways (2022) ERA vocabulary. Version v2.5.2. Retrieved from https://data-interop.era.europa.eu/era-vocabulary/

6. Acknowledgments

back to ToC

Contributors:
The following individuals have contributed to the development process of this ontology, at different stages of the development process:

Julián Rojas, (Ghent University - imec)
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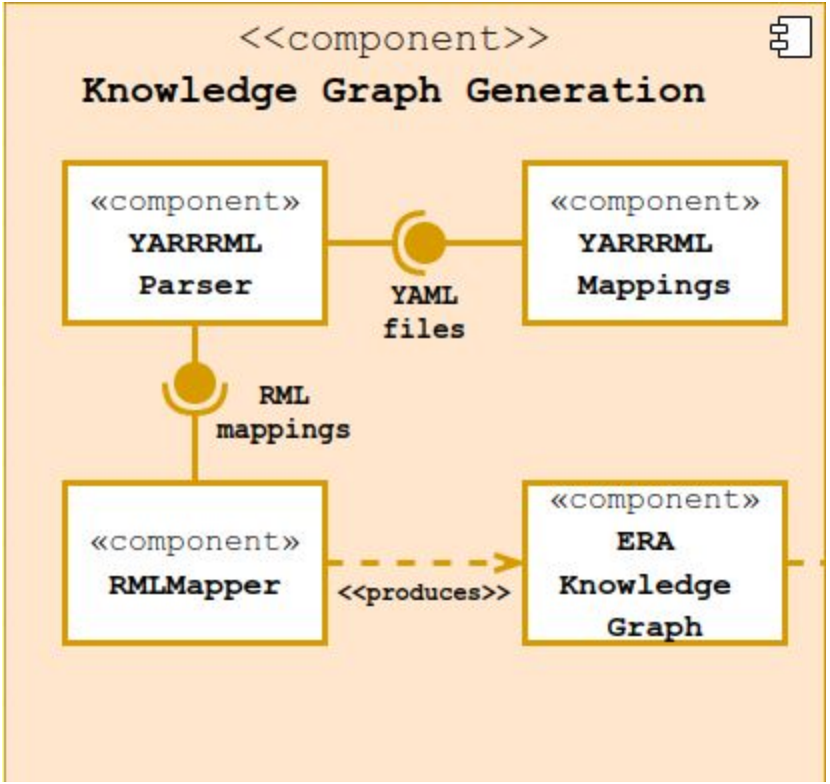
Ivo Velitchkov, (DG DIGIT)
Marina Aguado, (ERA)
Pieter Colpaert, (Ghent University - imec)
Polymnia Vasilopoulou, (ERA)
Edna Ruckhaus, (UPM)
Oscar Corcho, (UPM)
Wouter Beek, Triply

ACT II: Data mapping and integration

(YARR)RML-based mapping architecture

- A total of 775 YARRRML mappings have been written so far.

- Data sources include:
  - RINF and ERATV relational DBs
  - Norway and Sweden railML (XML)
  - ProRail connectivity data (CSV)
  - OpenStreetMap (XML)



The ERA **Knowledge Graph** in numbers

Live SPARQL endpoint: https://linked.ec-dataplatform.eu/sparql

~40 million triples

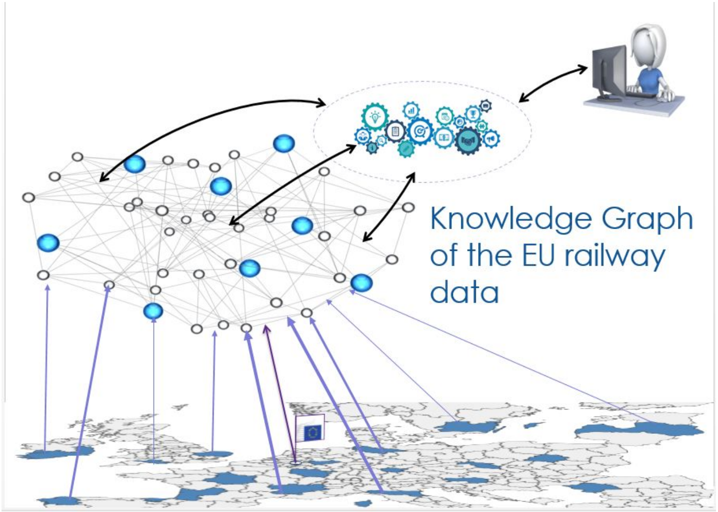
+270k Track segments described

+50k stations (aka Operational Points) described

+50k geo-referenced objects (lat/lon)

+2k Vehicle Types described

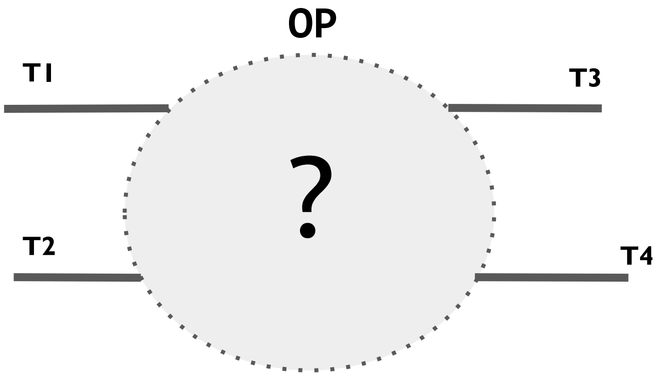
27 countries covered



+50 SKOS taxonomies: https://data-interop.era.europa.eu/era-vocabulary/skos/index.html

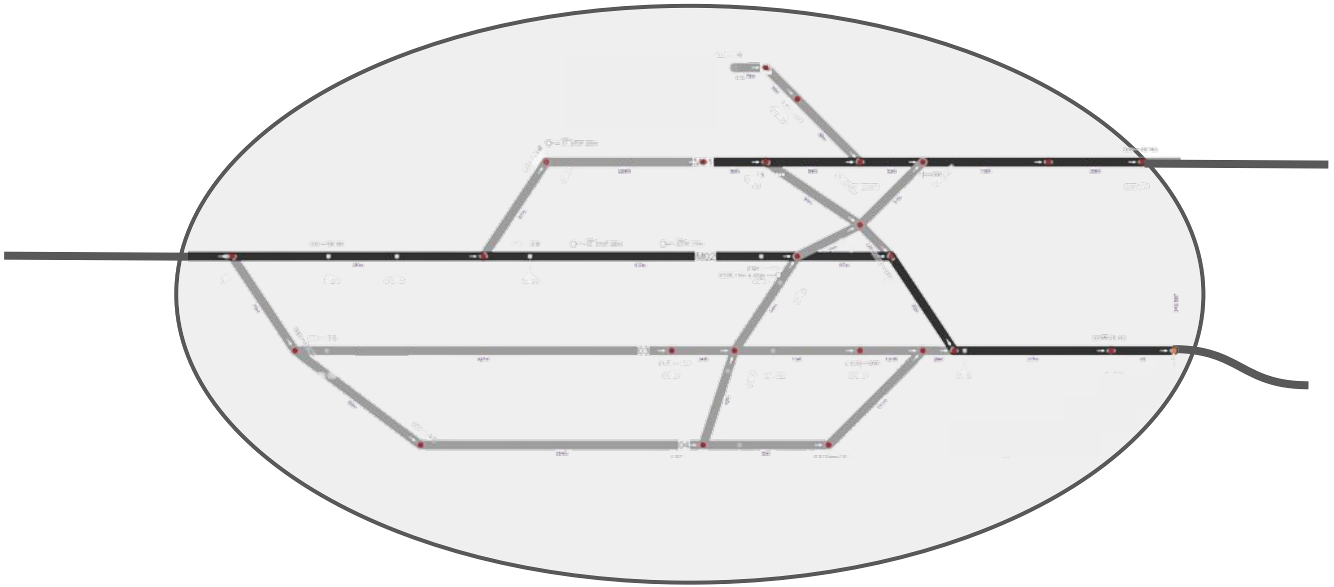
Data integration: micro-level topology with railML data

railML is a **railTopoModel-based** data model that envisions micro-level topology descriptions.



railML.org

For example the schematic topology* of **Dombas Station** in Norway



Dombas Station

* taken from Norway's railML data

The main mapping challenges are:

- Interlinking RINF-based tracks with railML-based net elements
- Stitch back the topology graph from file based partition

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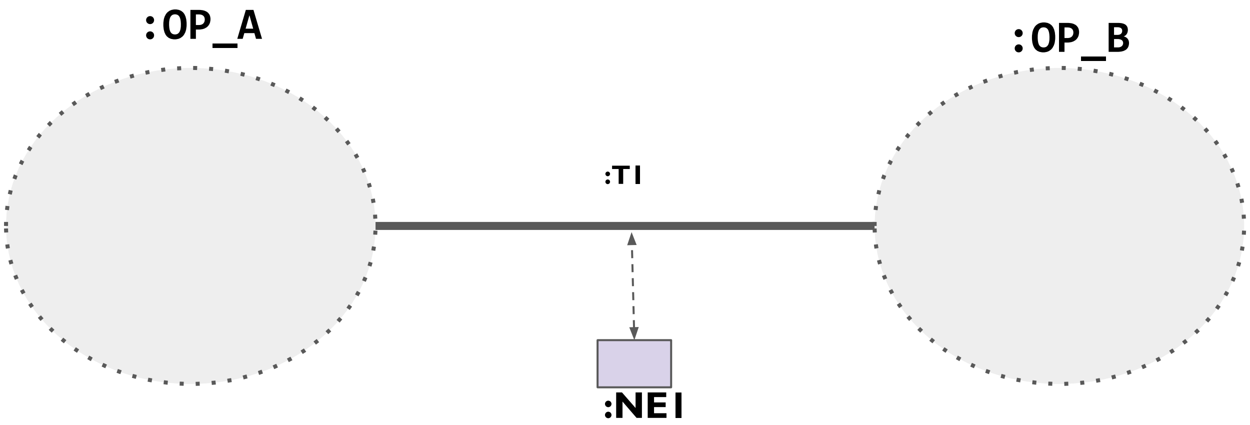

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- **Interlinking RINF-based tracks with railML-based net elements**
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```
source:
    - [data/norway-railml/BRB.railml~xpath, "//netElement[not(@length)]"]
  s: "$(('http://data.europa.eu/949/topology/netElements/' || ancestor::railML/metadata/dc:title || '_' || @id\\))"
  po:
    - p: era:hasImplementation # Link by circumstantial evidence based on the Kilometer points of FROM and TO OPs
      o:
        - mapping: rinf-sections-of-line
          condition:
            - function: idlab-fn:listContainsElement
              parameters:
                - [idlab-fn:str, $(FROM_KM), o]
                - [idlab-fn:list, "$( let $ne_id := @id return (ancestor::infrastructure//operationalPoint[
./@netElementRef = //netRelation[ ./elementA/@ref = $ne_id ]/elementB/@ref ]//@measure\\))", s]
            - function: idlab-fn:listContainsElement
              parameters:
                - [idlab-fn:str, $(TO_KM), o]
                - [idlab-fn:list, "$( let $ne_id := @id return (ancestor::infrastructure//operationalPoint[
./@netElementRef = //netRelation[ ./elementA/@ref = $ne_id ]/elementB/@ref ]//@measure\\))", s]
  graph: http://era.europa.eu/knowledge-graph/banenor
```

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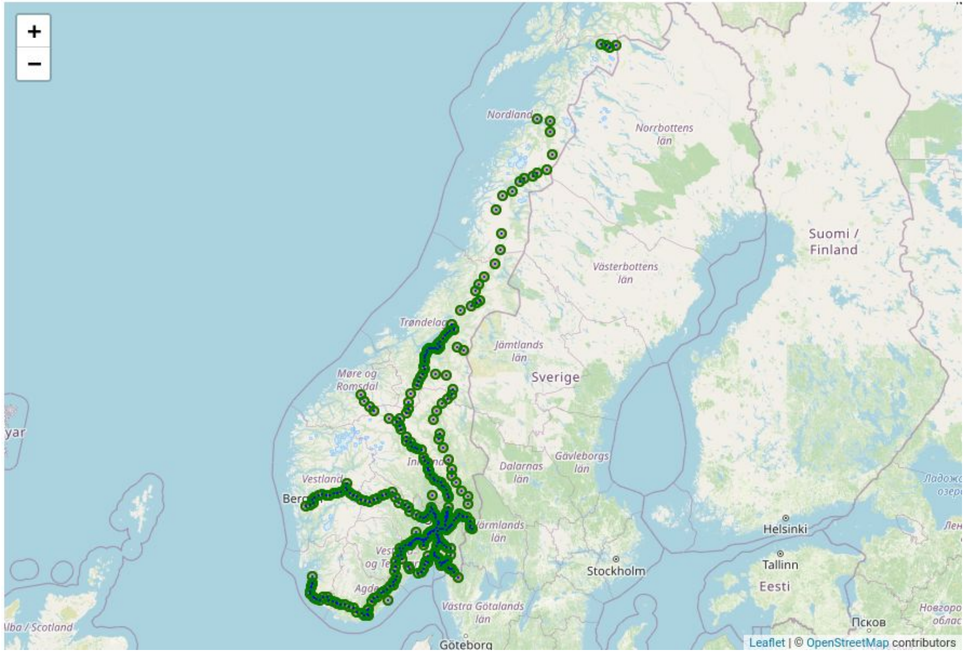
- **Interlinking RINF-based tracks with railML-based net elements**
- Stitch back the topology graph from file based partition

328 links created out of 375 possible ones (87%)



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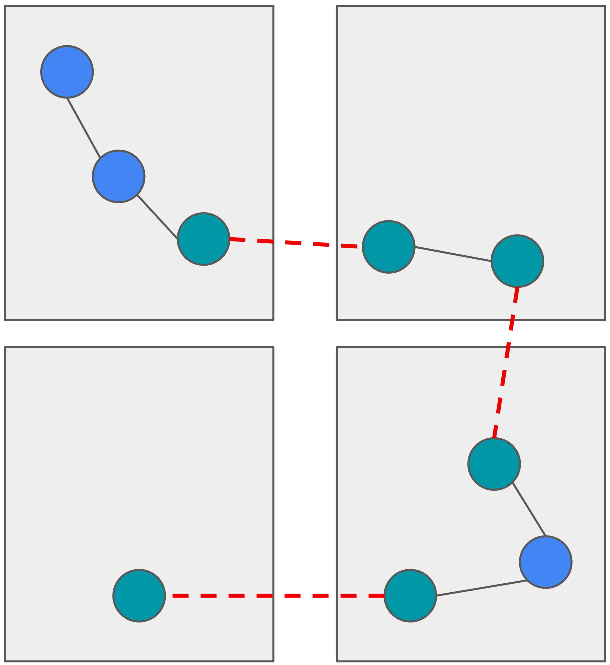


The main mapping challenges are:

- Interlinking RINF-based tracks with railML-based net elements
- **Stitch back the topology graph from file based partition**

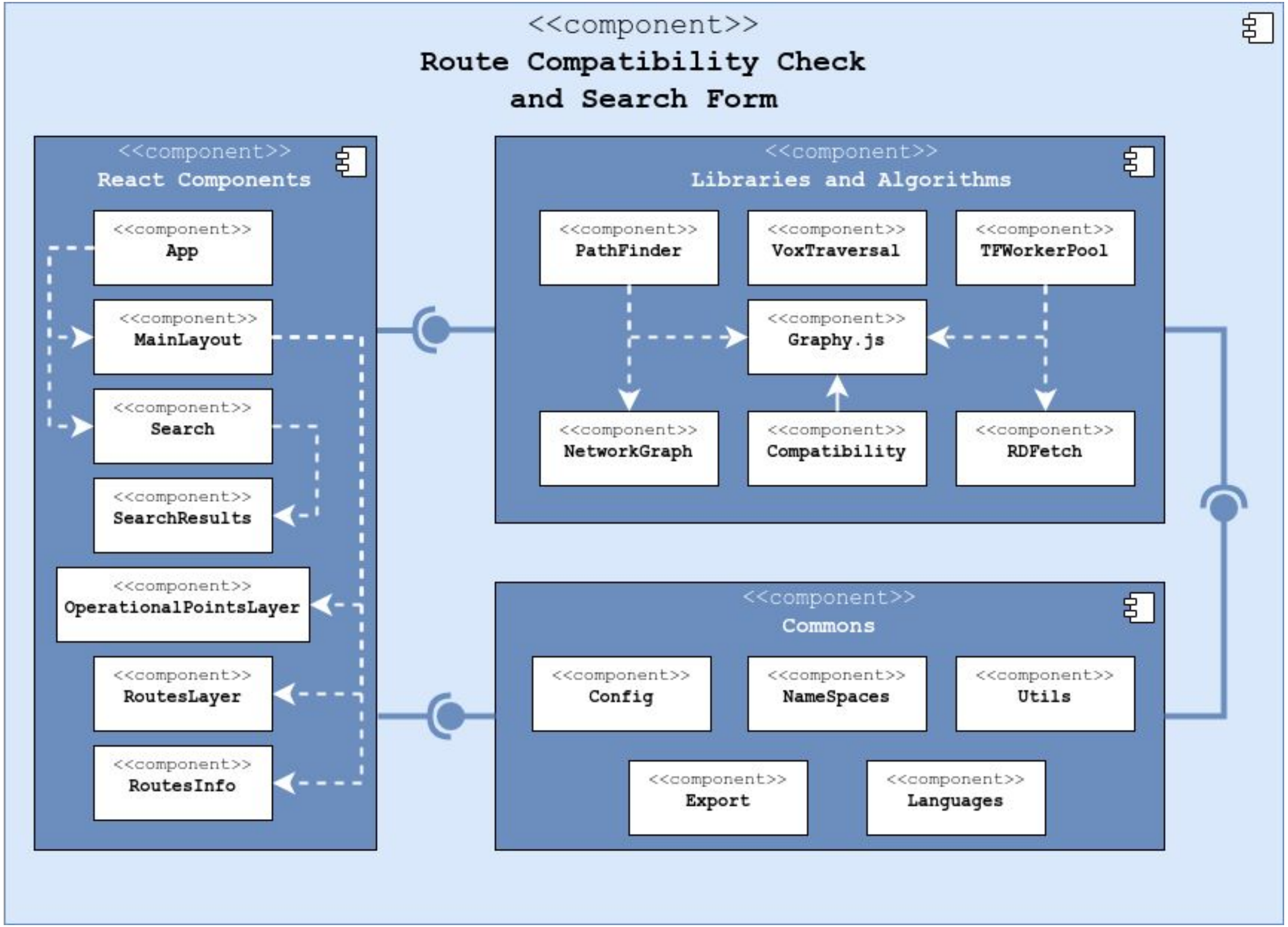
```
CONSTRUCT {
    ?bordNe era:linkedTo ?ne;
            era:partOf ?borderMesoNe;
            era:length ?length;
            geosparql:asWKT ?wkt.
} WHERE {
    ?border a era:Border;
            era:hasAbstraction ?bordNe.

    ?bordNe era:length ?length;
        ^era:elementPart ?borderMesoNe.

    ?mesoNr era:elementA|era:elementB ?borderMesoNe;
            era:elementB|era:elementA ?opMesoNe.
    ...
```

ACT III: Route compatibility check

The app:



<<component>>
Route Compatibility Check and Search Form
<<component>>
React Components
<<component>>
App
<<component>>
MainLayout
<<component>>
Search
<<component>>
SearchResults
<<component>>
OperationalPointsLayer
<<component>>
RoutesLayer
<<component>>
RoutesInfo
<<component>>
Libraries and Algorithms
<<component>>
PathFinder
<<component>>
VoxTraversal
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TFWorkerPool
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Graphy.js
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NetworkGraph
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Compatibility
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RDFetch
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Commons
<<component>>
Config
<<component>>
NameSpaces
<<component>>
Utils
<<component>>
Export
<<component>>
Languages

EUROPEAN UNION AGENCY FOR RAILWAYS

Route Compatibility Check | Search | English

Route Compatibility Check

From: Almere Centrum - NLALM

+ Via point

To: Dronten - NLDRON

11-054-0007-9-001 - TRAXX2E MS-KF4-D-A-B-NL-CZ-SK-H

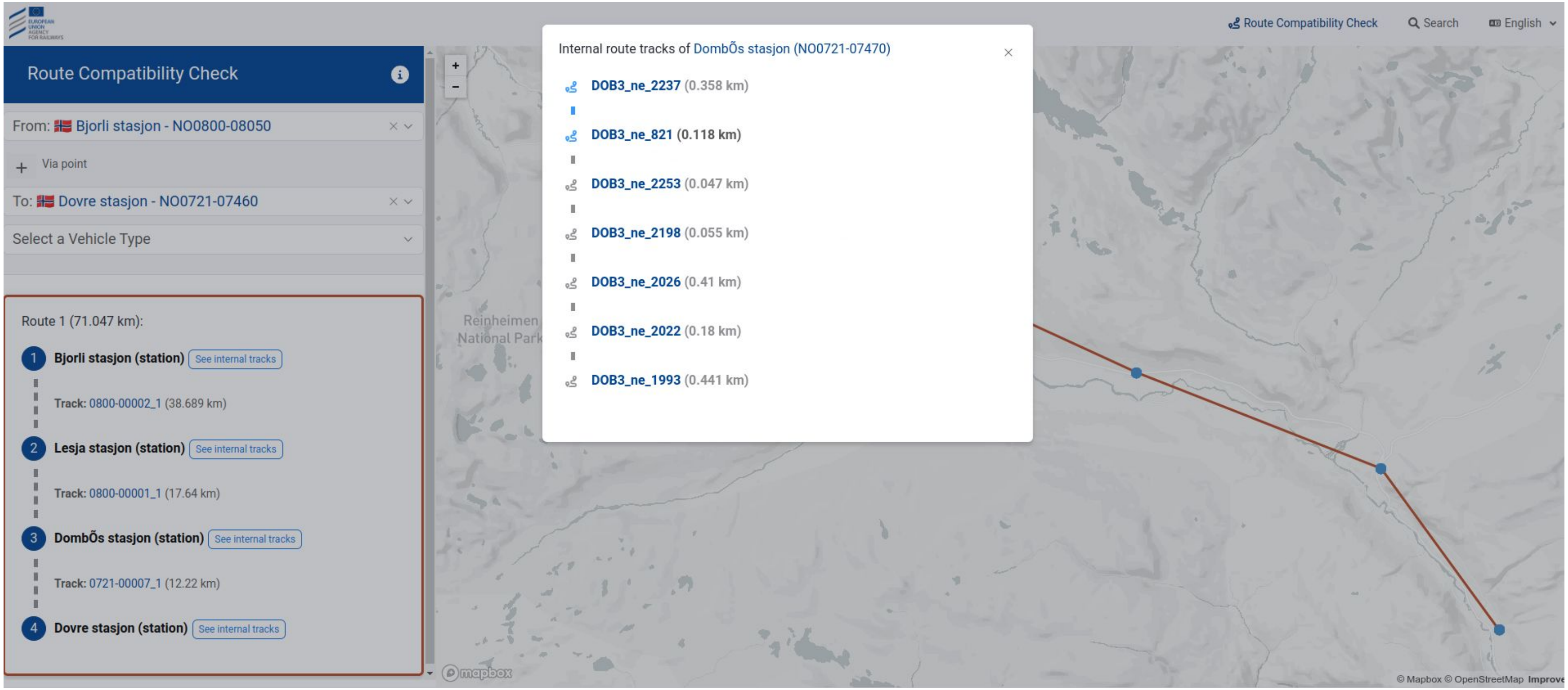
Route 1 (45.466 km):

1 **Almere Centrum (station)**

Track: FE
Vehicle Type: 11-054-0007-9-001

Properties	Compatible	Track	Vehicle
• Gauging	NO	NL1	G1
• Type of train detection system	YES	track circuit	• track circuit • wheel detector
• Existence of trackside hot axle box detector (HABD) • axle bearing condition monitoring	NO	false	Detectable by line side
• Rail			

The route calculated through Dombas station



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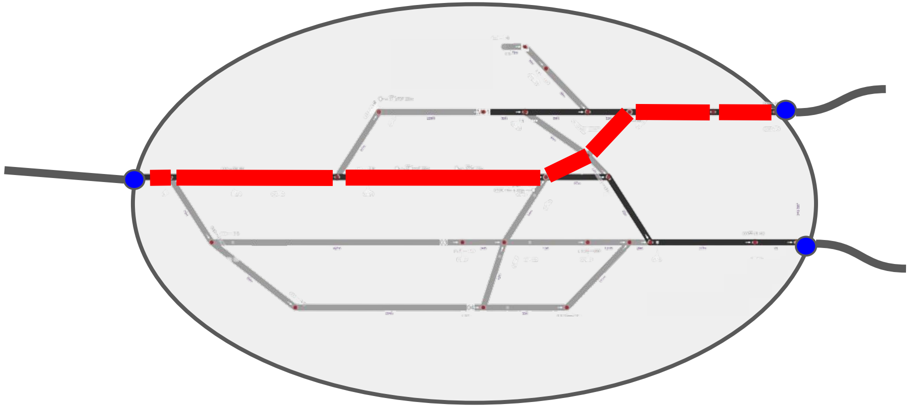


Dombas Station

Internal route tracks of DombÕs stasjon (NO0721-07470)

DOB3_ne_2237 (0.358 km)

DOB3_ne_821 (0.118 km)

DOB3_ne_2253 (0.047 km)

DOB3_ne_2198 (0.055 km)

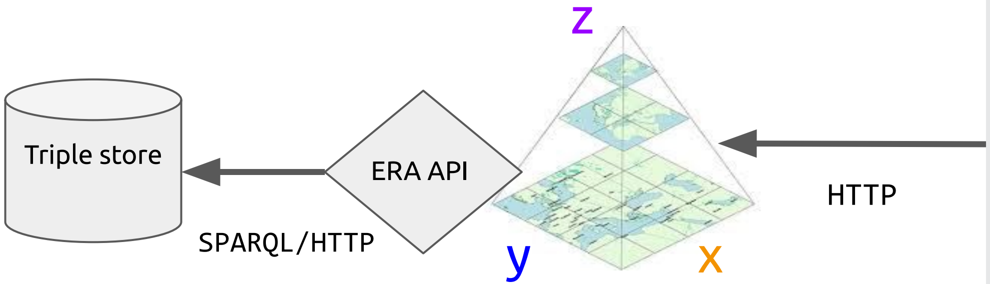
DOB3_ne_2026 (0.41 km)

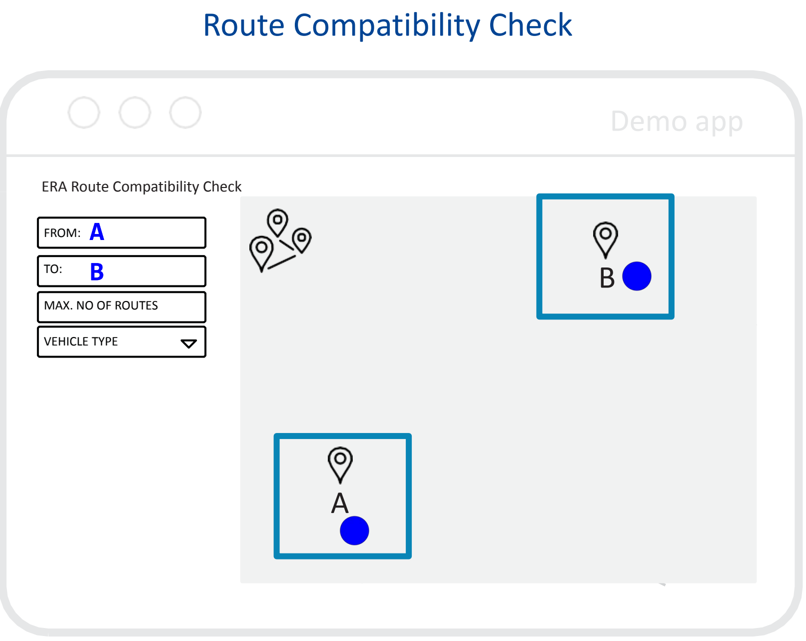
DOB3_ne_2022 (0.18 km)

DOB3_ne_1993 (0.441 km)

Route planning process flow

Step 1: Selection of **FROM** and **TO** Operational Points.





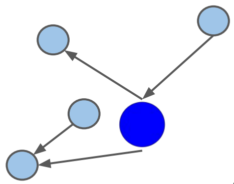
Fetching of (topological) data tiles related to FROM and TO operational points, e.g.:

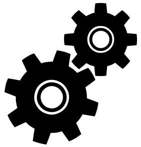
https://data-interop.era.europa.eu/ldf/sparql-tiles/abstraction/10/524/343

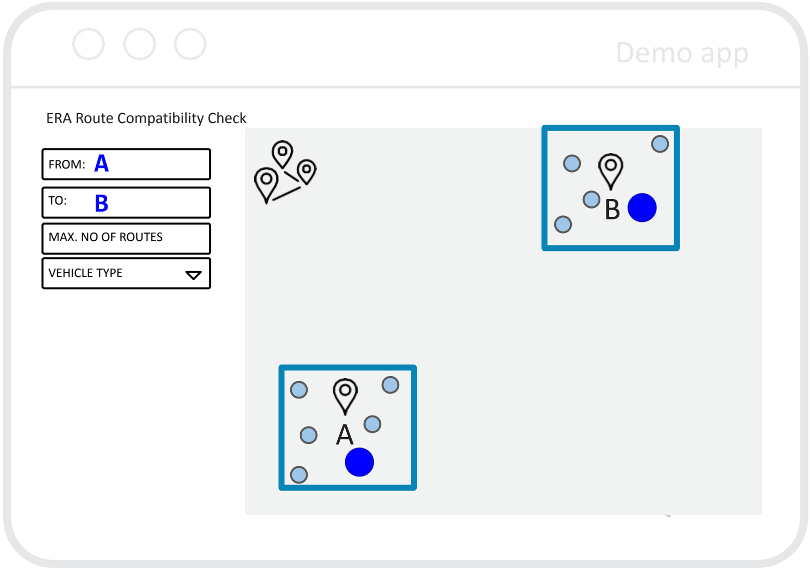
Route planning process flow

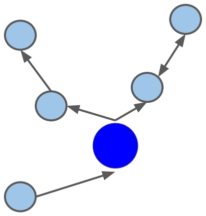
Step 2: Execution of shortest path algorithm (A*) and dynamic fetching of additional data tiles.

Route Compatibility Check









Route planning process flow

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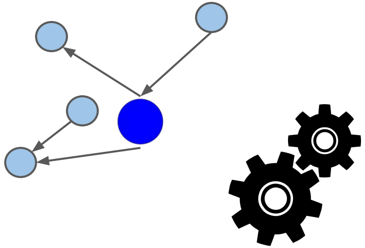

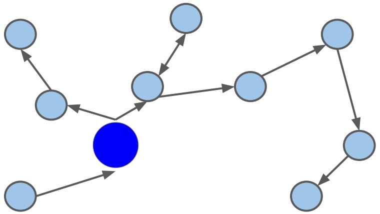

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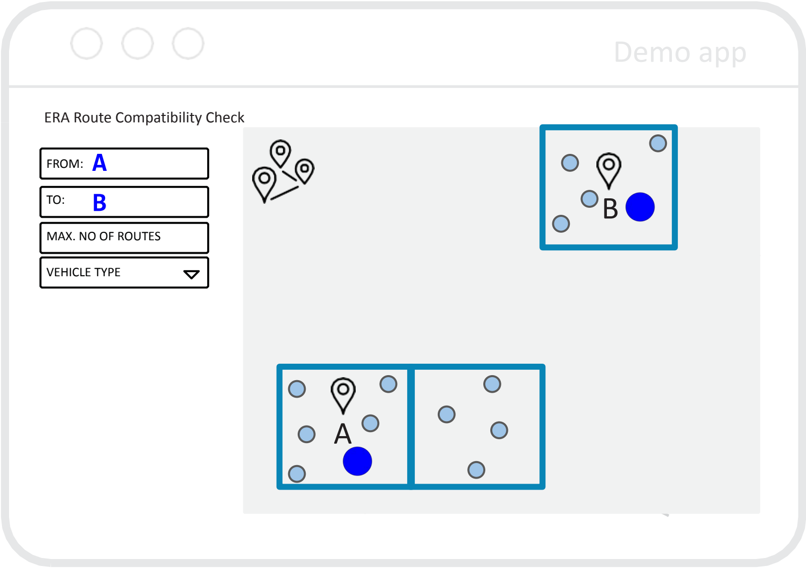

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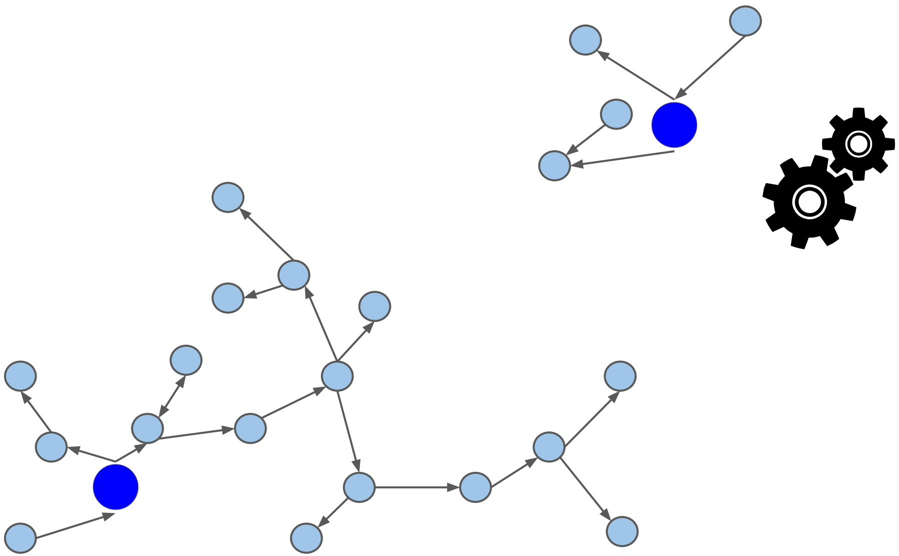

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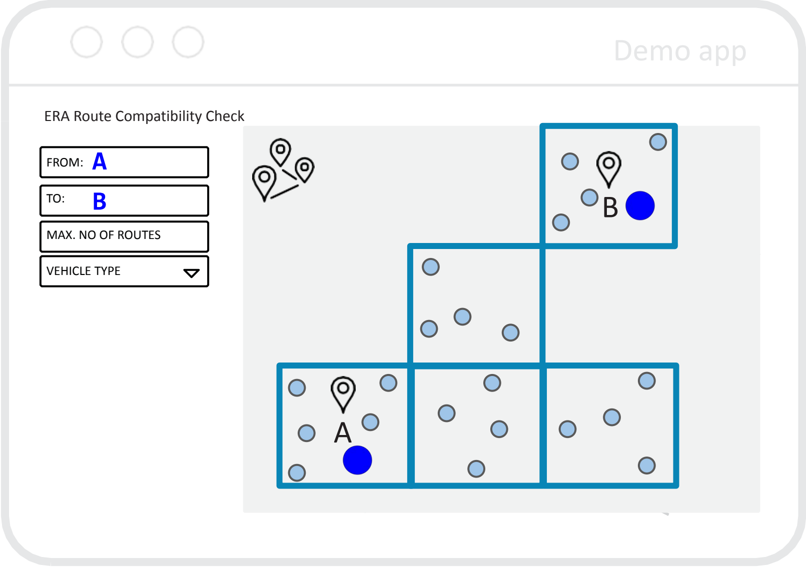

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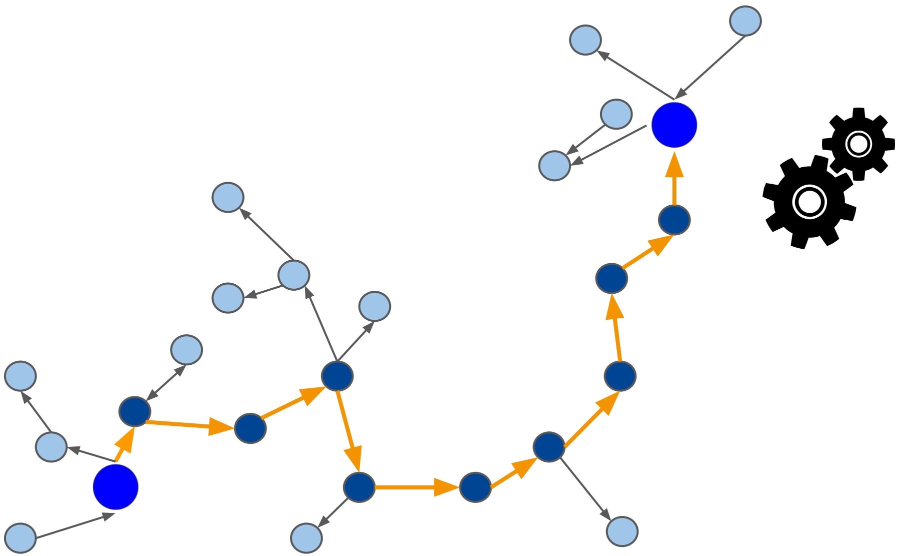
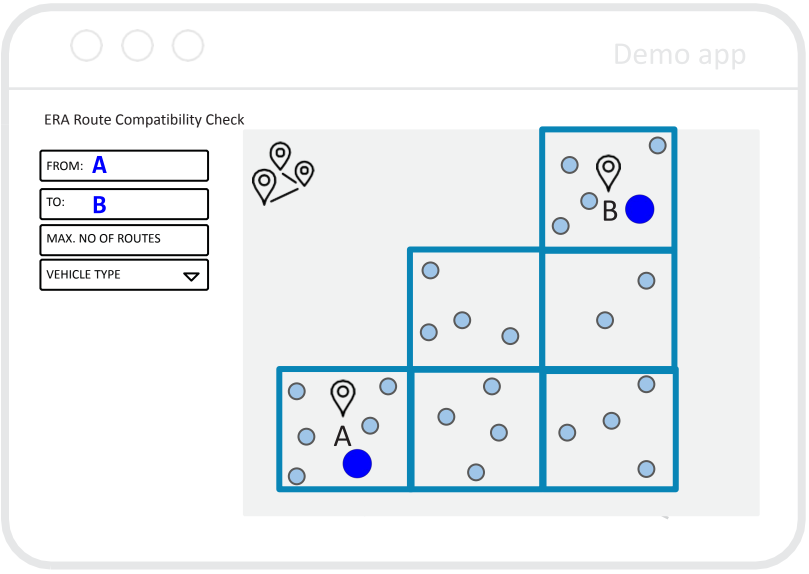
Step 2: Execution of shortest path algorithm (A*) and dynamic fetching of additional data tiles.

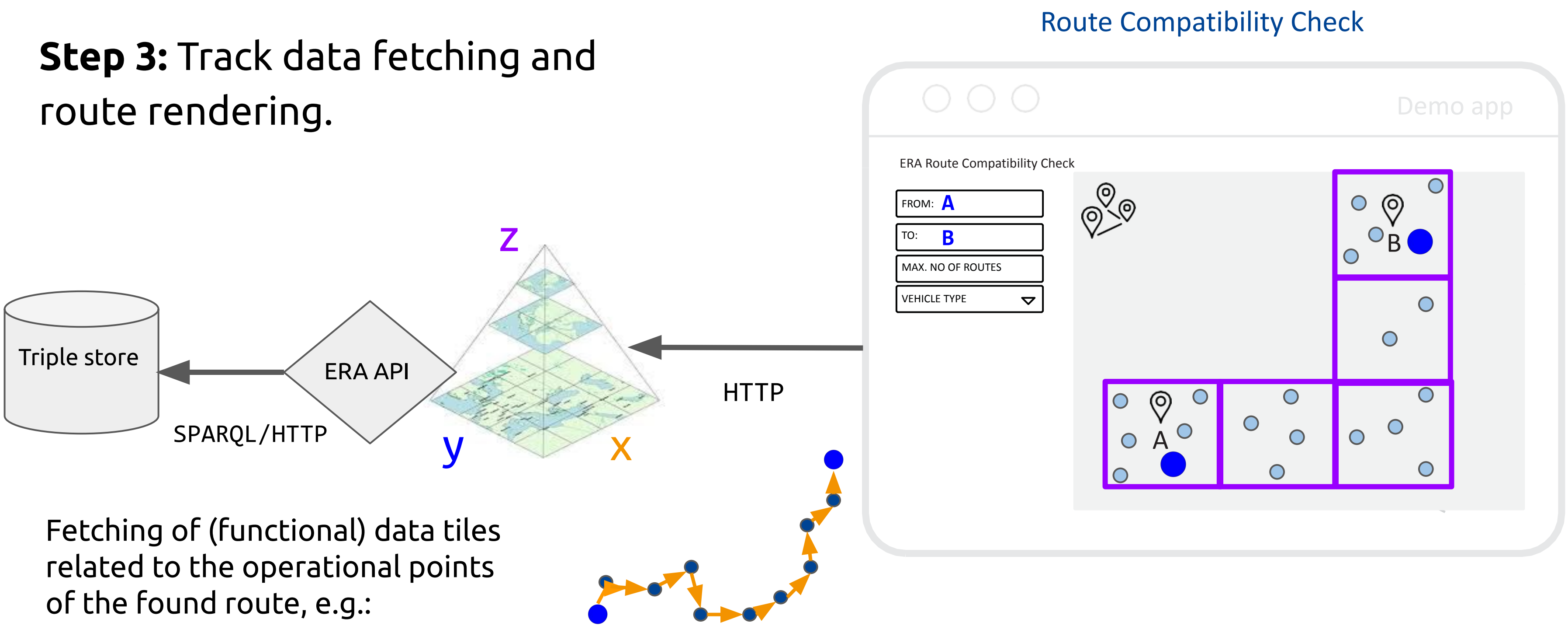


Route Compatibility Check



Route planning process flow

Step 3: Track data fetching and route rendering.

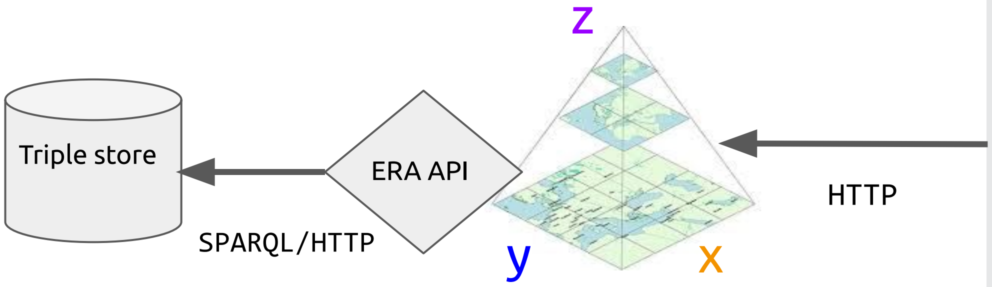


Fetching of (functional) data tiles related to the operational points of the found route, e.g.:

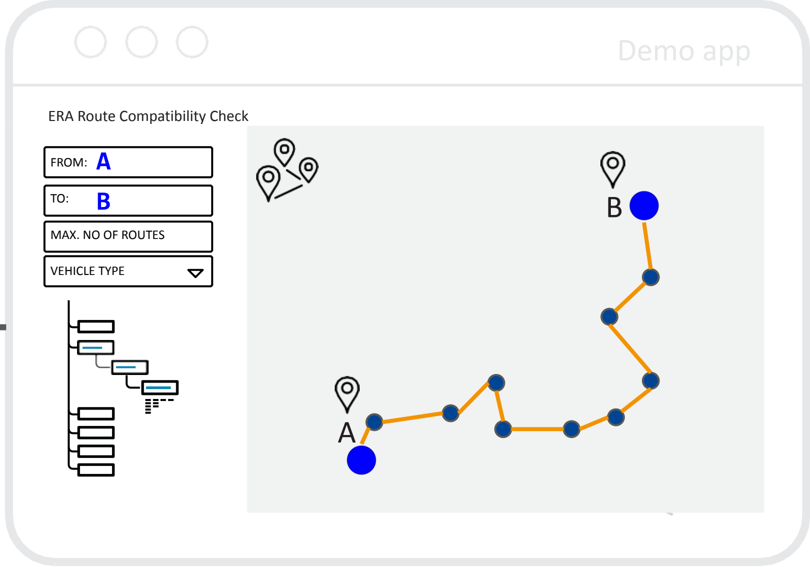
https://data-interop.era.europa.eu/ldf/sparql-tiles/implementation/10/524/343

Route planning process flow

Step 3: Track data fetching and route rendering.



Route Compatibility Check



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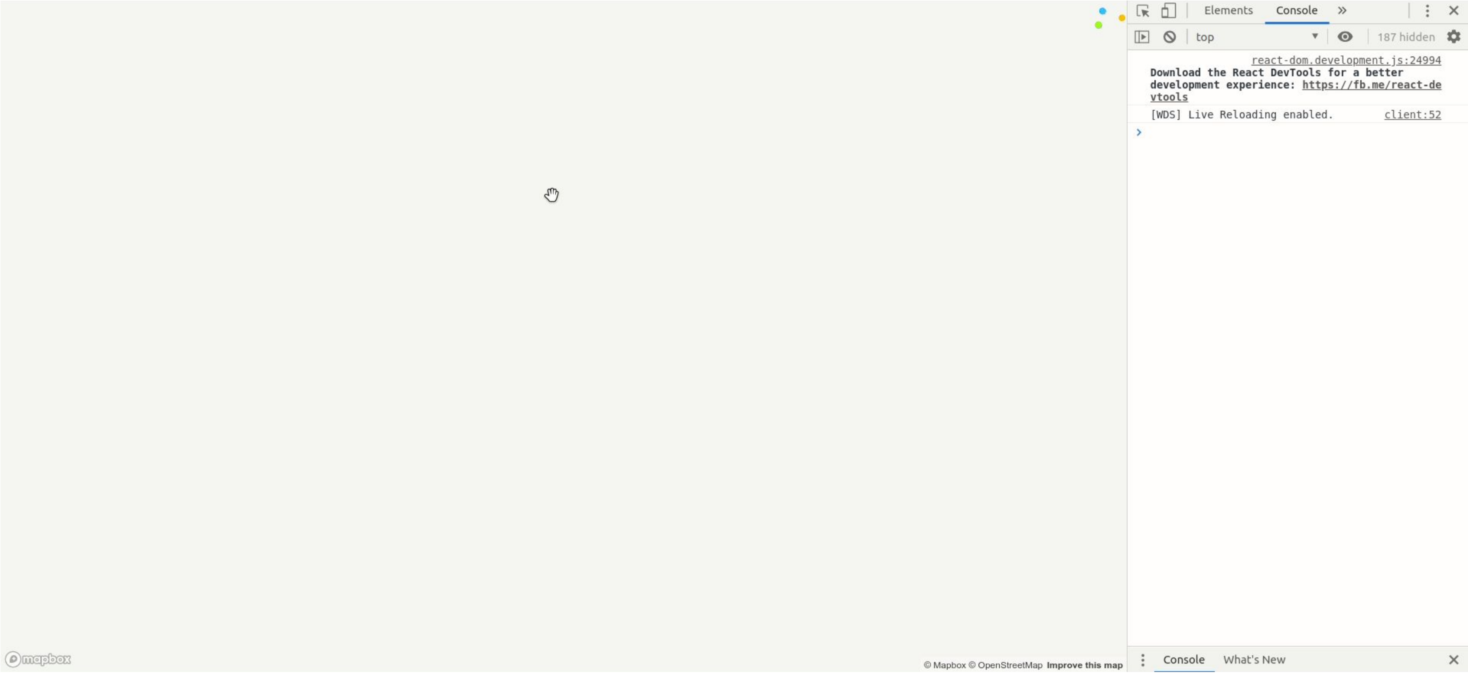
Route planning process flow



Pros and Cons of this approach

Pros

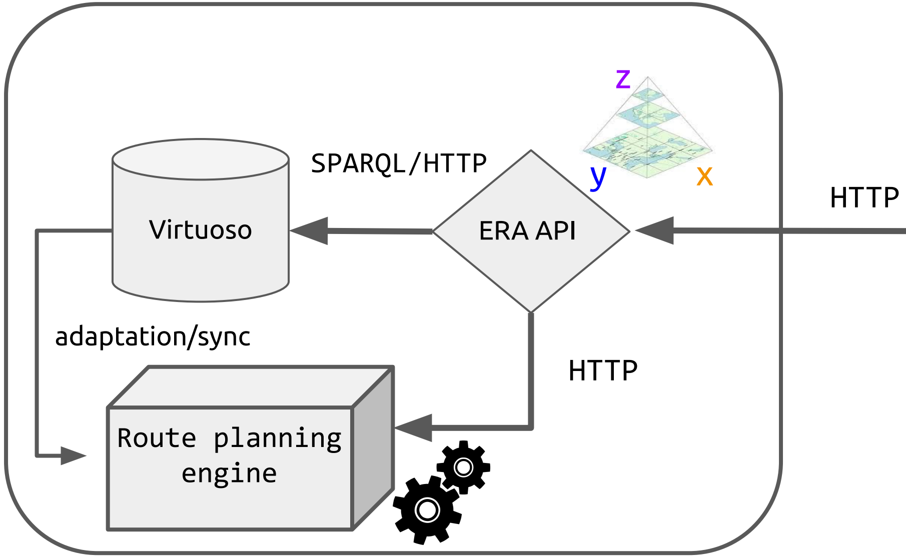
- Low server-side costs
  - High-cacheability of query responses
- Client-side autonomy for implementing customized route calculations

Cons

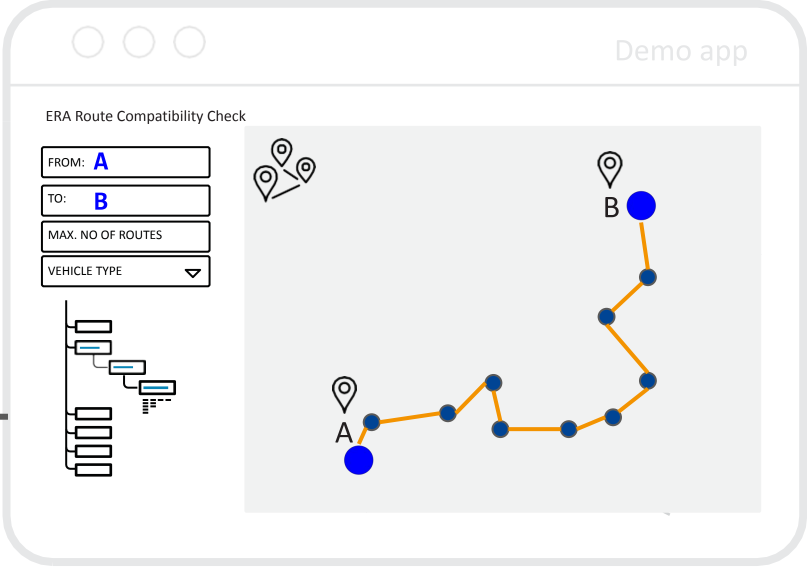
- Severe performance issues on long-distance routes

Potential solutions

Fully server-side route planning with dedicated engine

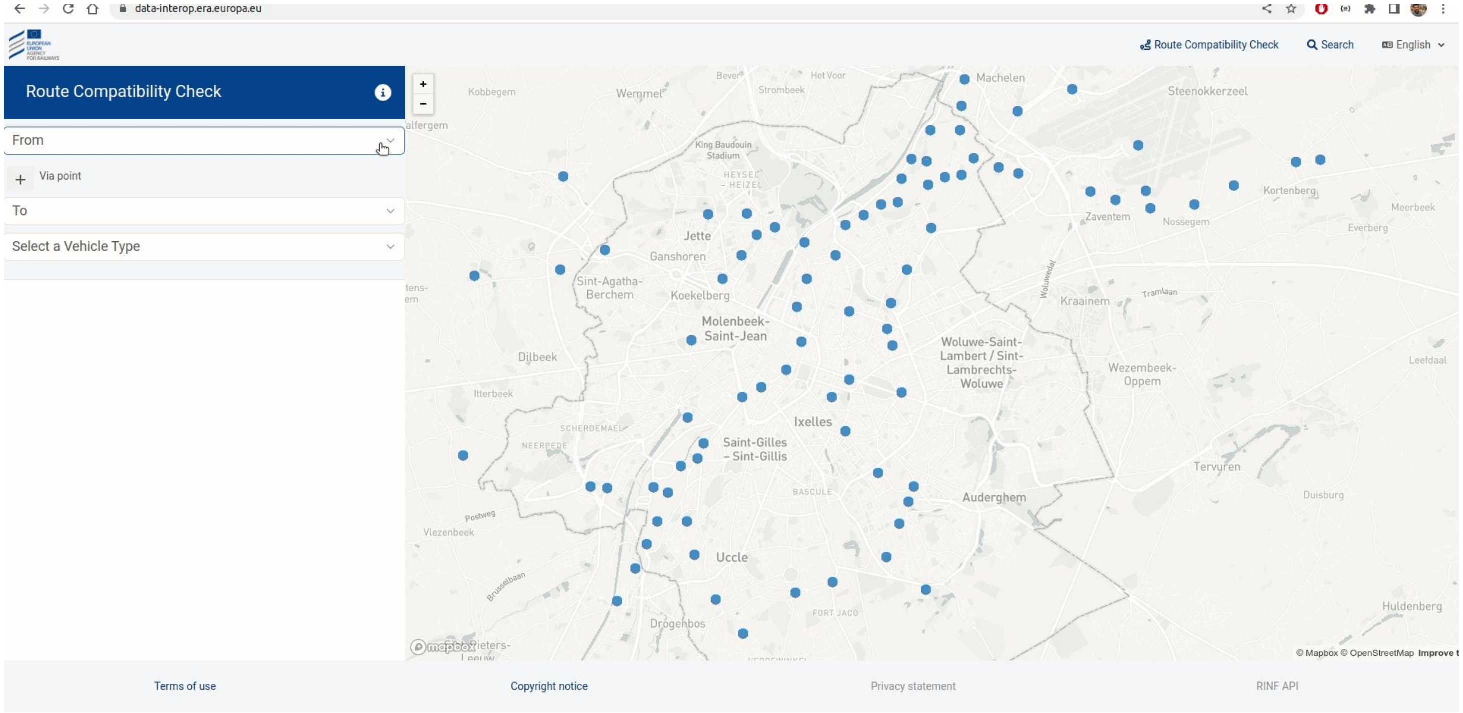


Route Compatibility Check



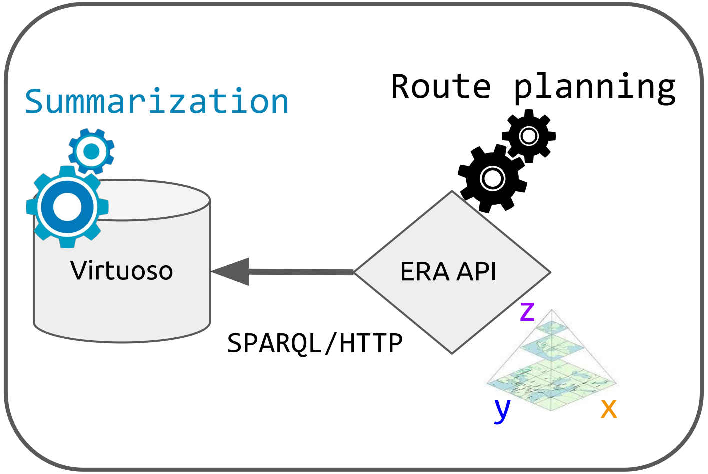
Potential solutions

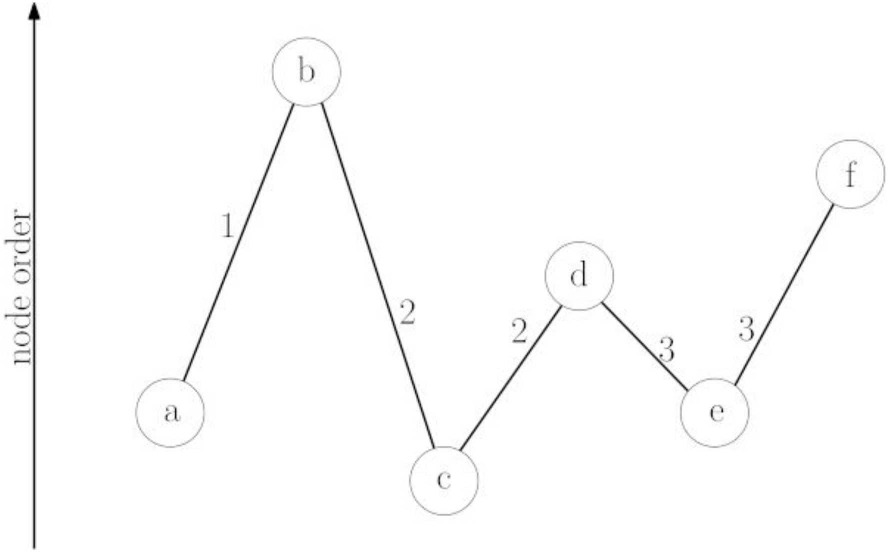
Fully server-side route planning with dedicated engine (OSRM)



Potential solutions

Summarization techniques for route planning (e.g. Contraction Hierarchies)



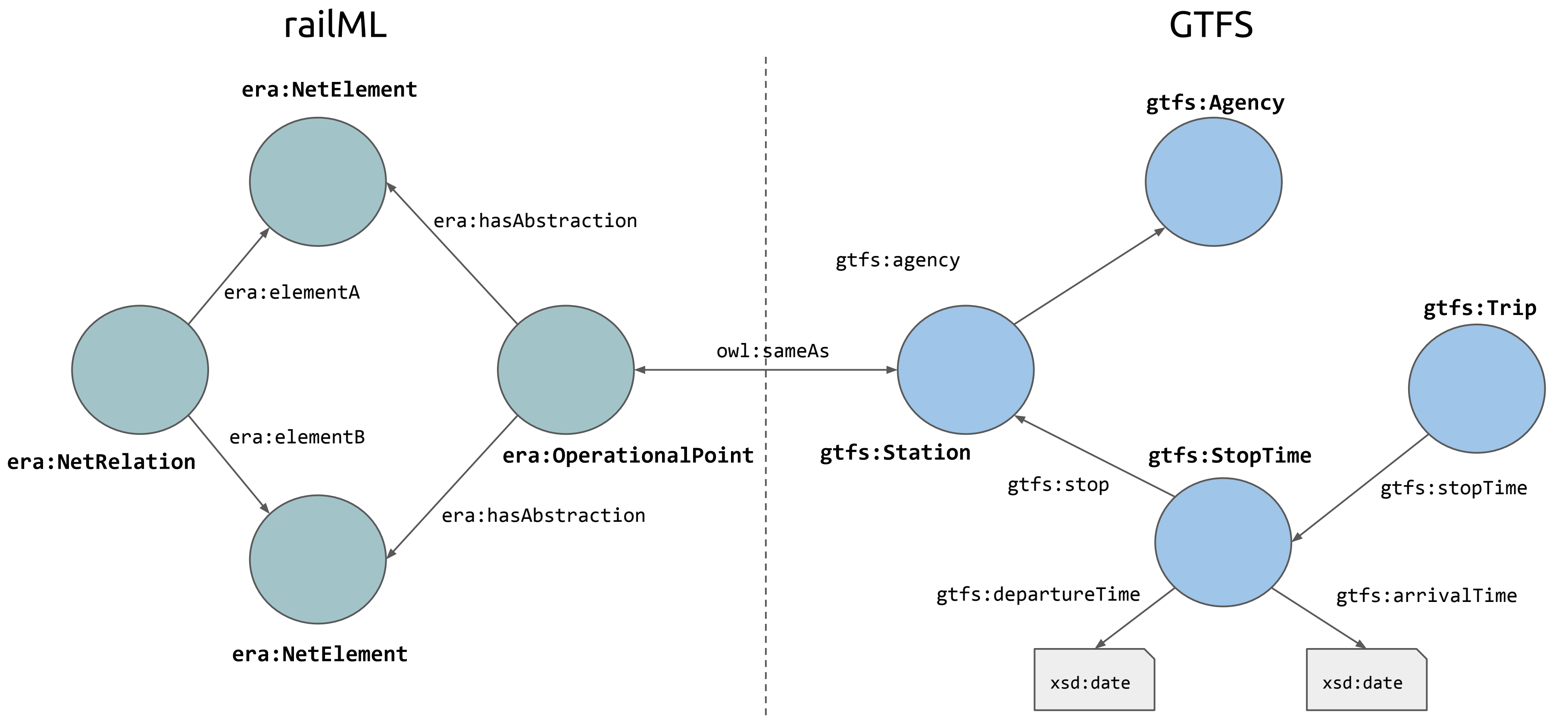


What does the future hold?

Next steps…

- SHACL-based quality assessment
- SHACL rules-based compatibility assessment
- OSM integration for geometry extraction
- Summarization techniques for optimizing route planning queries
- Schedule data integration (e.g., GTFS, NeTEx)
- LDES-based replication architecture

Ontology-based interoperability example for railML and GTFS

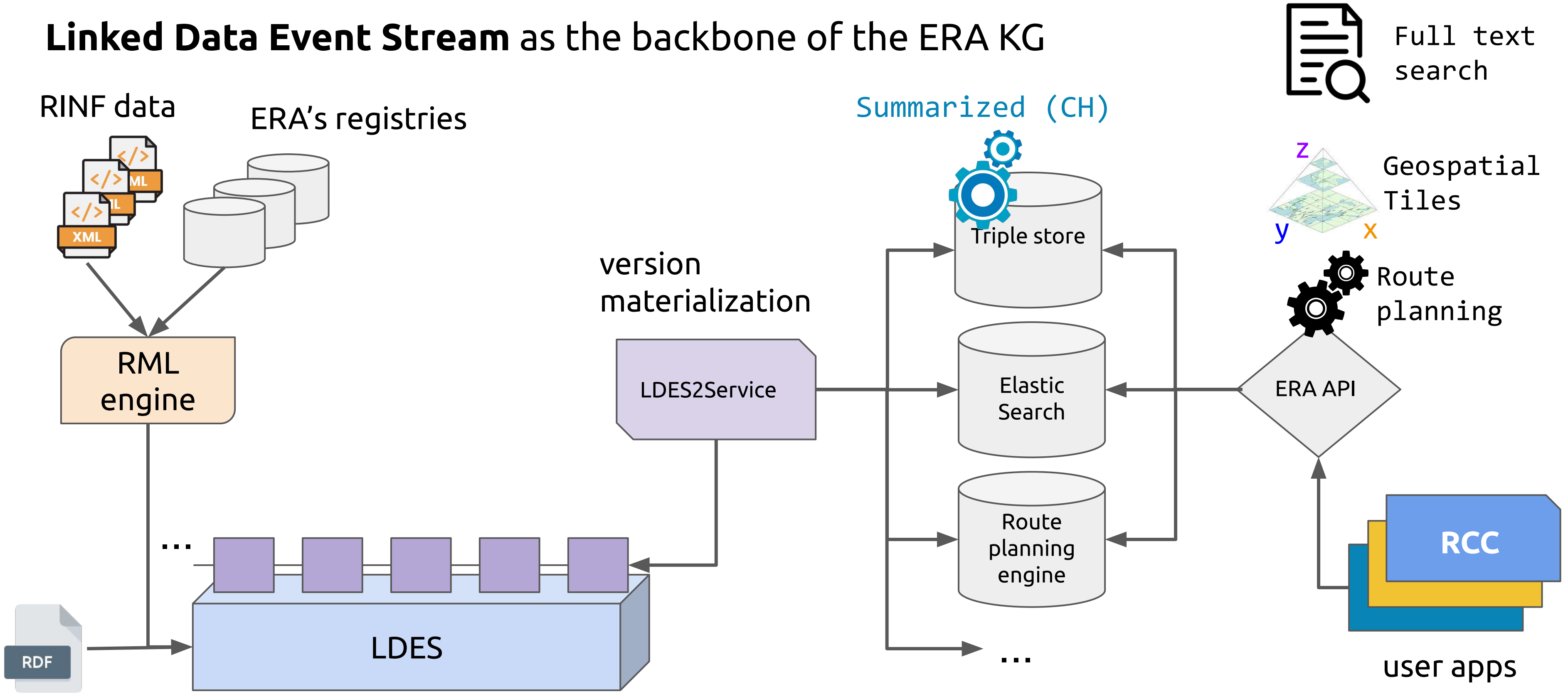


era: http://data.europa.eu/949/

gtfs: http://vocab.gtfs.org/terms#

LDES-based replication and sync

Linked Data Event Stream as the backbone of the ERA KG



Takeaways

- ✓ Thanks to this work ERA set Knowledge Graphs as the default setting for future data endeavors.
- ✓ Knowledge graph technologies can fulfill the requirements of transport data use cases (although there is room for improvement)
- ✓ Balance the trade-offs of data integration (mapping time vs querying time) and query execution (client- vs server-side)

Building a KG for the European Railway Agency: The story

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