IN2DREAMS

Welcome by the Project Coordinator

STEFANOS GOGOS (UNIFE)

IN2DREAMS Final Conference, Milan, 02.10.2019

IN2DREAMS Final Conference Agenda

Time	Topic	Speaker
09:00 – 10:00	**Registration and welcome coffee**	
10:00 – 10:05	Welcome address	Stefanos Gogos (UNIFE)
10:05 – 10:15	Introduction by Shift2Rail	Sébastien Denis (Shift2Rail JU)
10:15 – 10:30	IN2DREAMS introduction	Stefanos Gogos (UNIFE)
10:30 – 11:00	Integrated Communication Platform	Markos Anastasopoulos (University of Bristol)
11:00 – 11:30	Sensing/Monitoring Devices and Data Management Platform	Guillaume Pelletier (Dotvision)
11:30 – 12:00	User Applications	Simona Soldi (Evolution Energie)
12:00 – 12:30	Smart metering demo	Markos Anastasopoulos (University of Bristol) Guillaume Pelletier (Dotvision)
12:30 – 13:30	**Networking Lunch**	
13:30 – 14:00	Smart contracts for Railway Data Transactions	Nadia Fabrizio (CEFRIEL)
14:00 – 14:30	Knowledge extraction from Railway Asset Data	Davide Anguita (Uni. of Genoa)
14:30 – 14:55	Proof of Concept	Nadia Fabrizio (CEFRIEL) Davide Anguita (Uni. of Genoa)
14:55 – 15:00	Closing remarks	Stefanos Gogos (UNIFE)
15:00	**Networking Coffee**	

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Introduction by Shift2Rail

SÉBASTIEN DENIS (SHIFT2RAIL JU)

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IN2DREAMS Introduction

STEFANOS GOGOS (UNIFE)

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IN2DREAMS

Facts & Figures

Total Budget
2.2M

Duration
26 Months

Partners
14

Start Date
01/09
2017

Contact
Stefanos Gogos
Project Coordinator
stefanos.gogos@unife.org

www.in2dreams.eu

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Project Partners

PROJECT COORDINATOR

unife THE EUROPEAN RAIL INDUSTRY

TECHNICAL LEADERS

Datvision

UNIVERSITÀ DEGLI STUDI DI GENOVA

BENEFICIARIES

Cefriel POLITECNICO DI MILANO

Evolution Energie

IASA

ISKRATEL

KU LEUVEN CENTRE FOR IT & IP LAW

LEM

pureLiFi

RINA

RFI RETE FERROVIARIA ITALIANA GRUPPO FERROVIE DELLO STATO ITALIANE

University of BRISTOL

Universität Konstanz

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Challenge & Scope

- Predicted growth of transport, especially in European railway infrastructures, is expected to introduce a dramatic increase in freight and passenger services by the end of 2050.
- To support sustainable development of these infrastructures, novel data-driven ICT solutions are required.
- These will enable monitoring, analysis and exploitation of energy and asset information for the entire railway system including power grid, stations, rolling stock and infrastructure.
- IN2DREAMS addressed these challenges through two distinct work streams: Work Stream 1 (WS1), focusing on the management of energy-related data and Work Stream 2 (WS2), focusing on the management of asset-related data

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High-level Objectives

Work Stream 1 – Management of Energy-related Data

WS1 aimed at removing the current and anticipated limitations of REMS, by making these capable of supporting a much wider array of requirements than it is currently the case.

Work Stream 2 – Management of Asset-related Data

WS2 aimed at improving efficiency and sustainability of the railway asset data management, by applying research advances in machine learning, data visualization and decentralized architecture with smart contracts.

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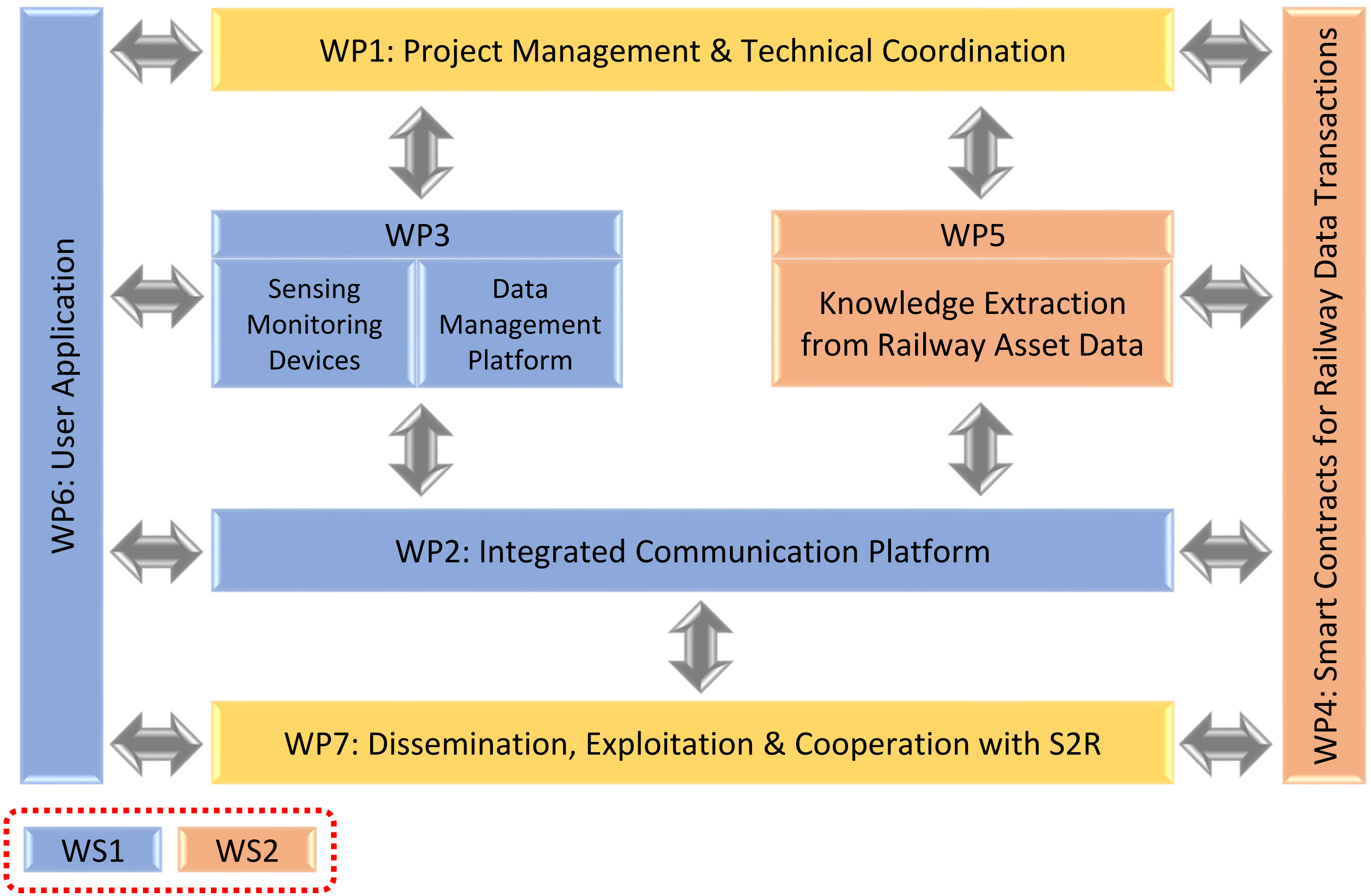
IN2DREAMS Project Structure



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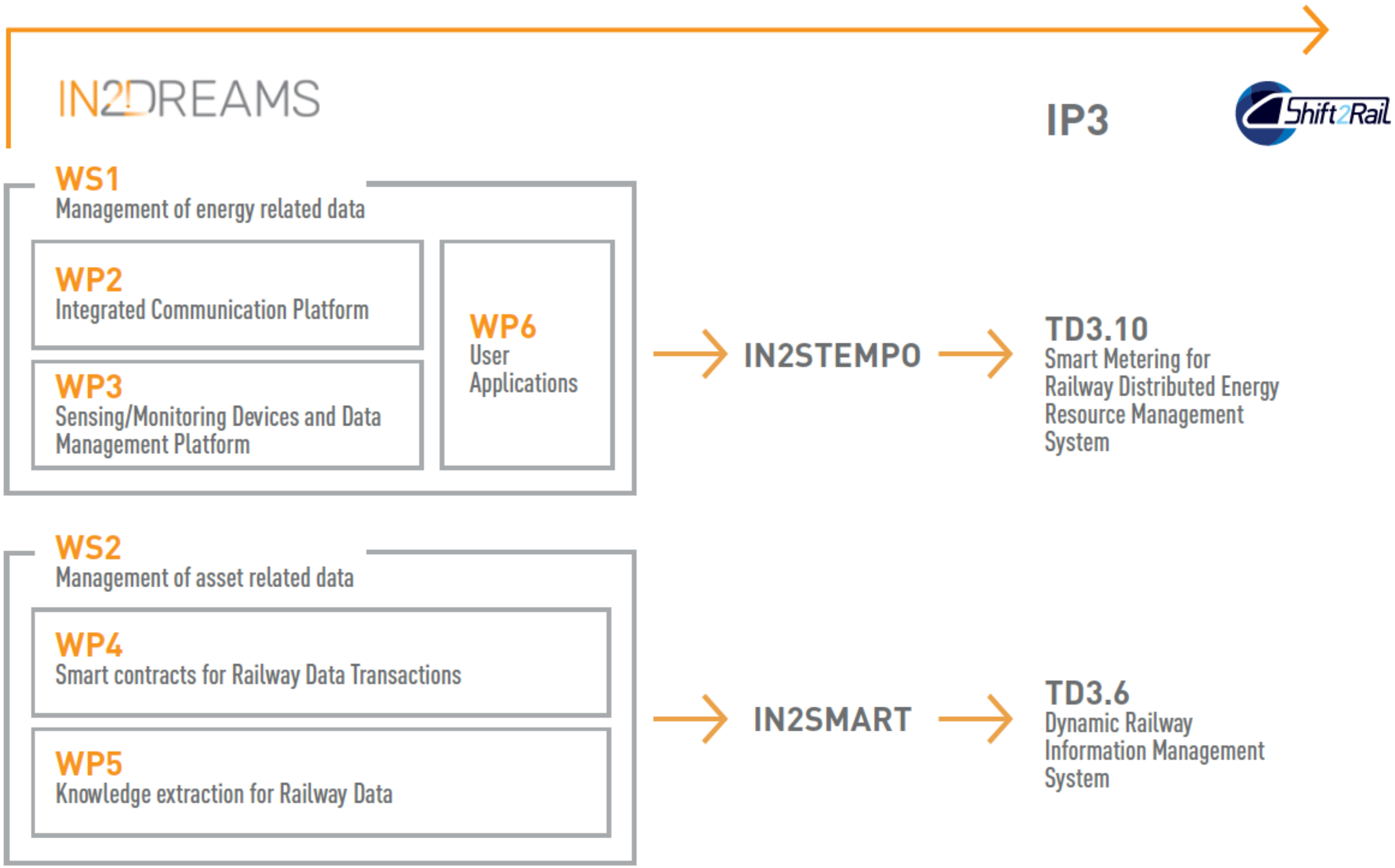
Links with Shift2Rail



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Integrated Communication Platform

MARKOS ANASTASOPOULOS (UNIVERSITY OF BRISTOL)

IN2DREAMS Final Conference, Milan, 02.10.2019

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Outline

5G systems

- *Motivation: 5G Vision*
- *Overview of 5G architectures: The IN2DREAMS solution*
- *IN2DREAMS Building blocks (Multi-technology access, Heterogeneous Transport Network Interconnecting Compute Resources with Remote Radio Units)*

On – Board Solution

- *WiFi/LiFi/LTE*
- *Dimensioning*

Trackside Solution

- *FSO/Optical/*
- *Control Plane*

Conclusions

Shift2Rail

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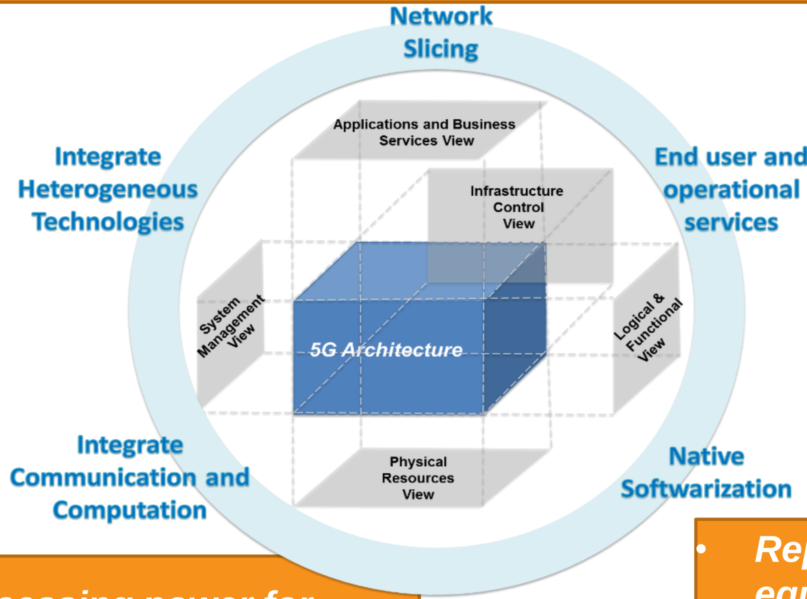
Motivation - 5G Vision

Deploy a communication infrastructure able to support a large variety of services and applications for the railway industry. Specific use case: Smart Energy metering.

- *Common Platform for ALL services*
- *Efficient resource sharing and multi-tenancy*



- *Multi-technology networks for access and transport*
- *Improved efficiency, capacity etc*

- *Multiplexing of Mission Critical Services with Passenger services*
- *Multiplexing of Telecom with end user services*

- *Provides the necessary processing power for computational intensive tasks AI, ML, NN etc*
- *Supports delay sensitive services (i.e. using MEC)*

- *Replacement of costly equipment with general purpose devices*
- *Paradigm shift from Network Entities to Network Functions*

5G PPP View on 5G Architecture – (White Paper), https://5g-ppp.eu/white-papers/

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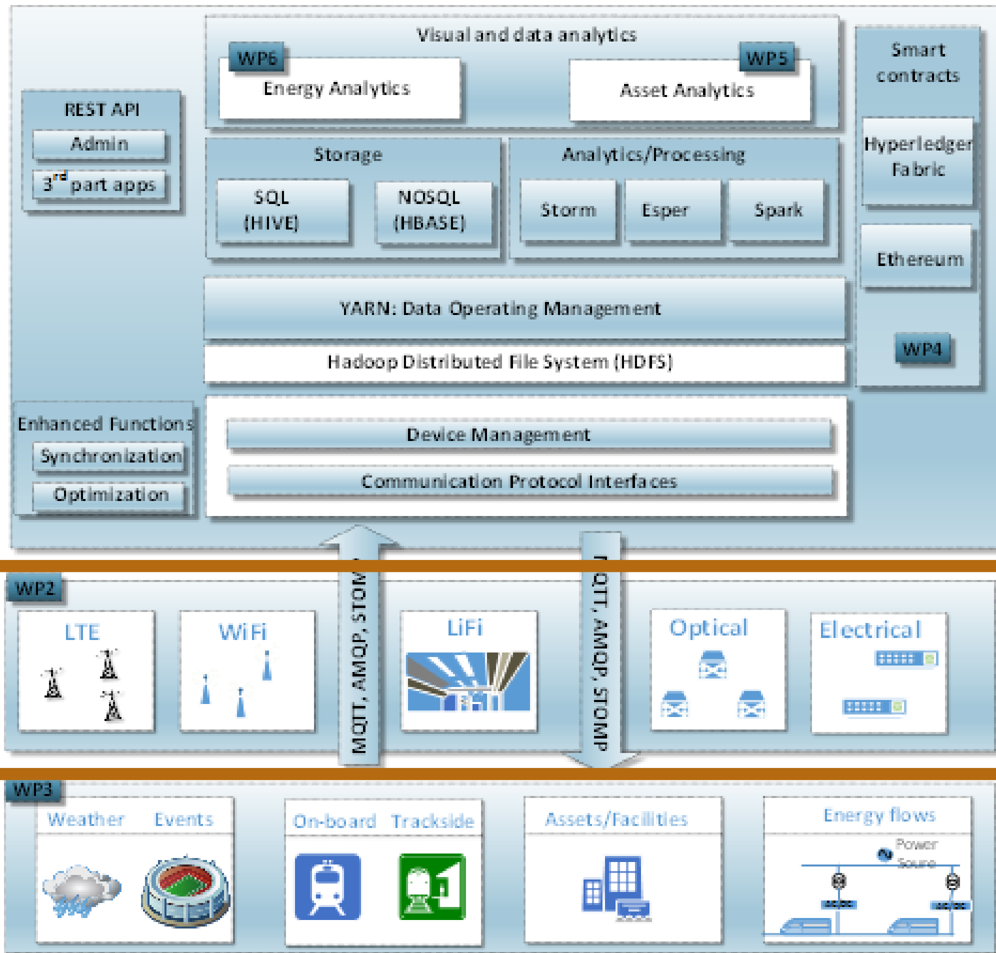
T2.1 Services, Use Cases, Architecture

Goal: Define the Architecture of the In2Dreams Solution
Partners: RINA-C, UNIVBRIS, IASA, DOTVISION, PURELIFI, ISKRATEL



Operational Data Management Platform

WP2

Integrated Communication Platform

Sensing/Monitoring Devices

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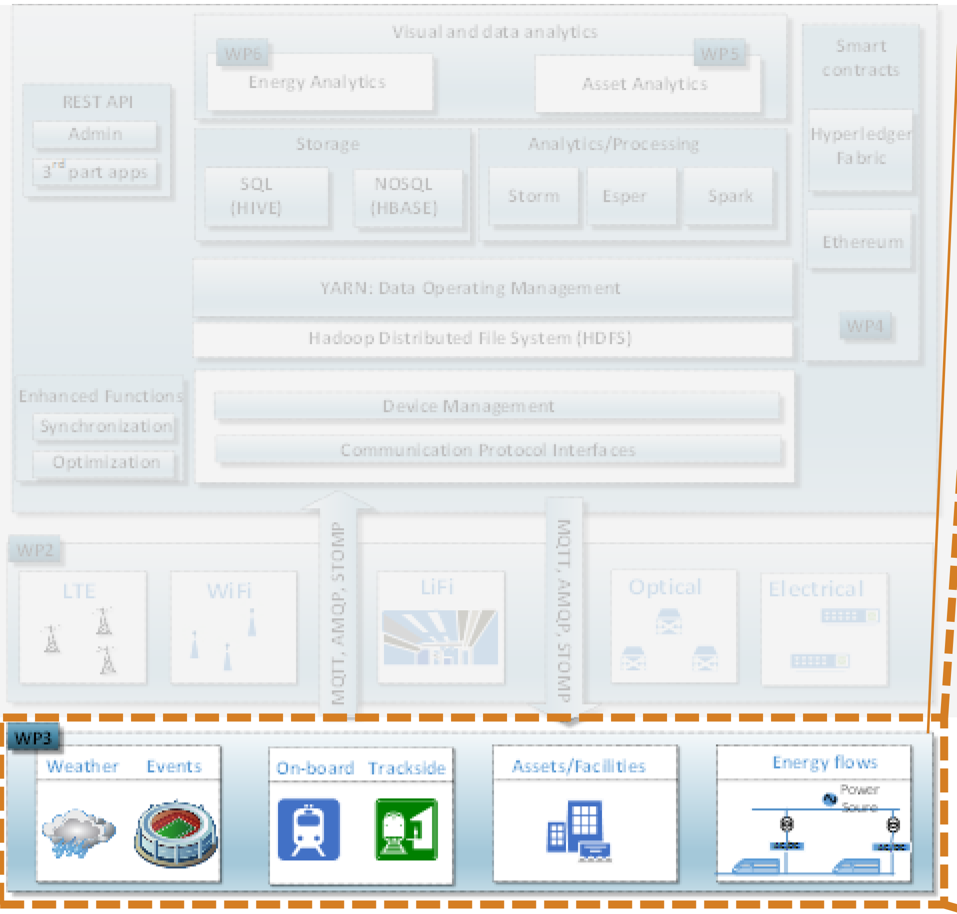
Building blocks (I)



Sensing/Monitoring Devices and Data Management Platform

- Interconnecting a variety of sensing and monitoring devices providing on-board and track side energy measurements.
- Supporting applications related to surveillance, observation, monitoring of environmental parameters (temperature, CO2, humidity, noise), energy monitoring (voltage, current), localization and environmental parameters.

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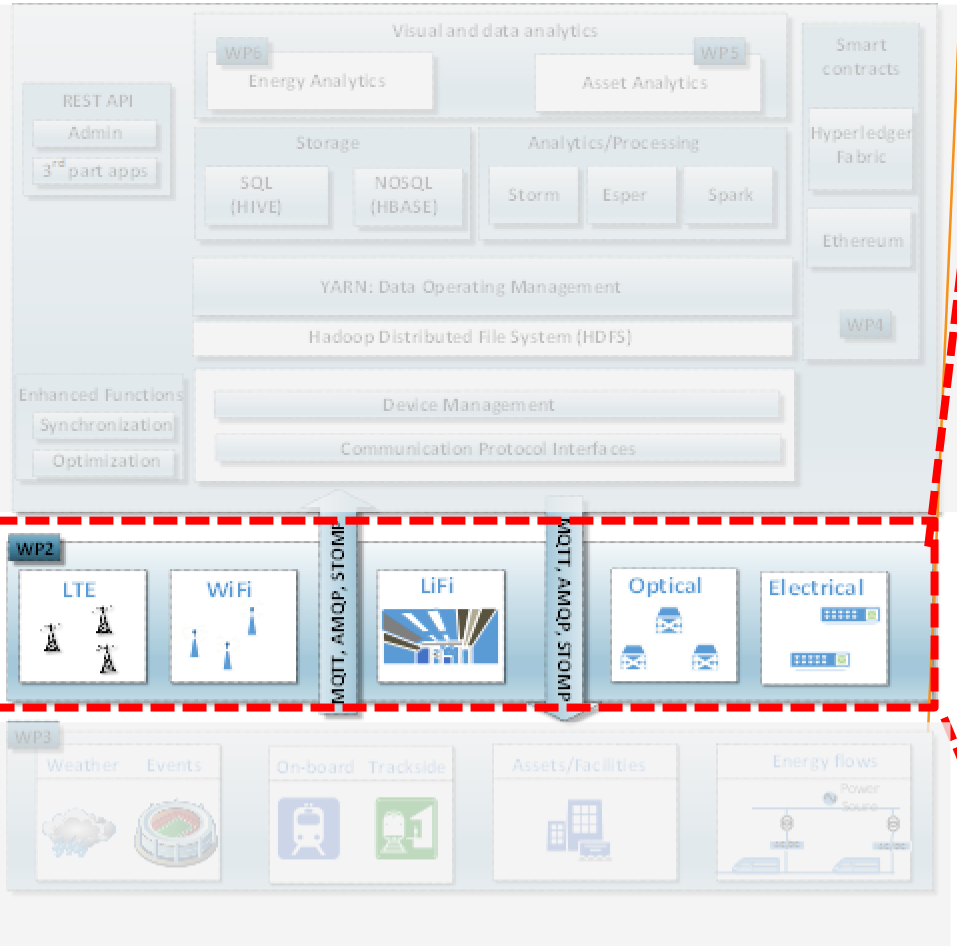
Building blocks (II)



Integrated Communication Platform

- Based on a heterogeneous secure and resilient telecommunication platform, consisting of both wireless (e.g. Long Term Evolution – LTE, WiFi, LiFI) and wireline (e.g. optical) systems converging energy and telecom services.
- This infrastructure interconnects a plethora of monitoring devices and end-users to the OSS.
- Control and management of the integrated network infrastructure using an open SDN-based network management framework

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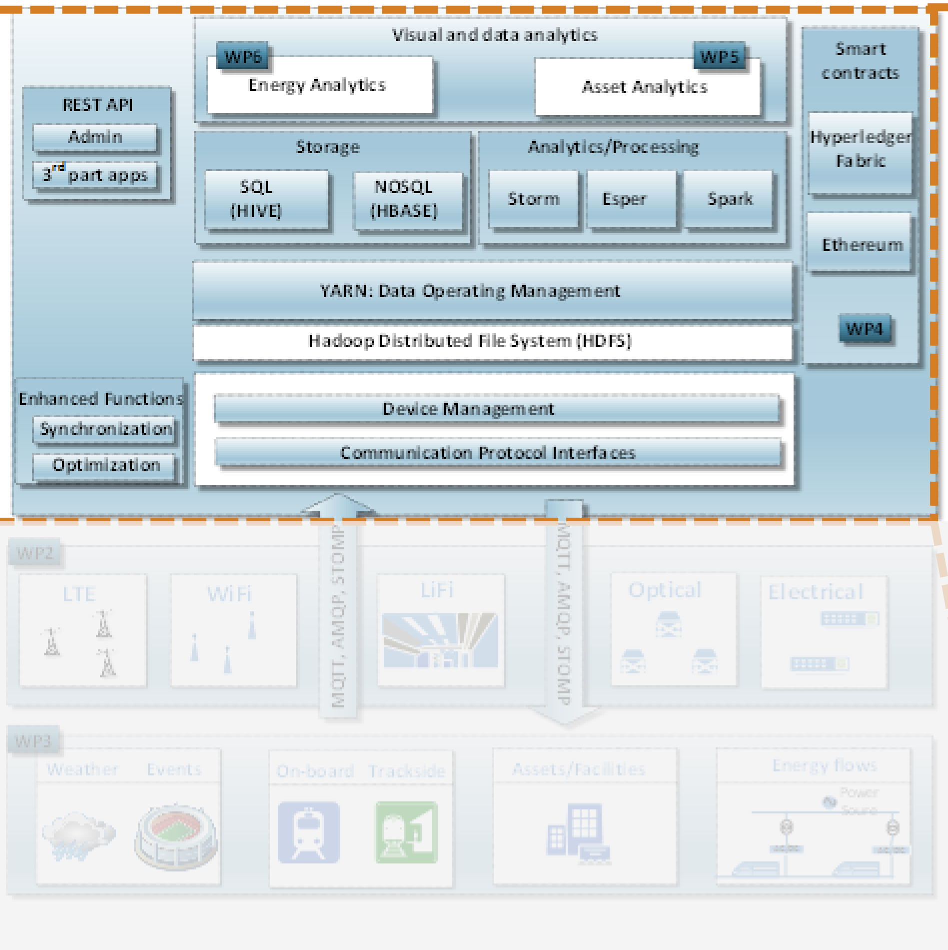
Building blocks (III)



ODM Platform

ODM platform offering Scalable Data Collection, Aggregation, Processing and Interfaces offering the following features:

- Operation in accordance to the cloud computing paradigm
- Secure access to data based on a proven user management system
- Hybrid scalable data storage mechanisms based on open source SQL/Non-SQL DBs
- Large-scale data processing engine to execute machine learning, (de) compression algorithms or extracting analytics data.
- Multi-protocol support: MQTT, AMQP, Sockets, etc).
- Synchronization

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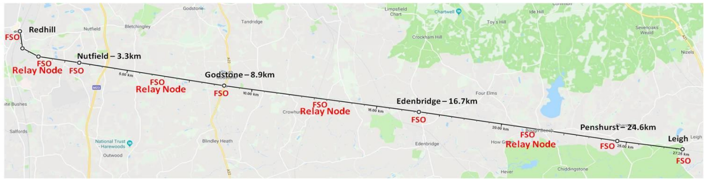
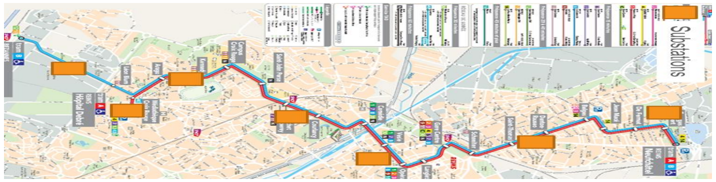
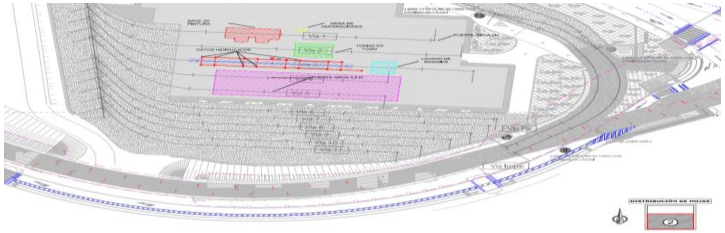
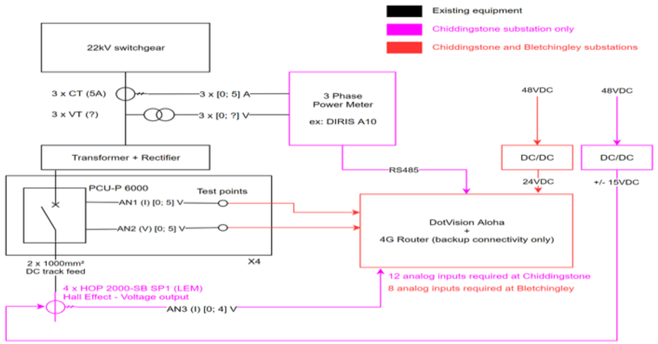
Use cases

- ***Use case 1: Commercial Line Operation***
  - Baseline: Smart energy metering for the REIMs tramway
  - Extension: Metering use case for a commercially operated railway line under normal traffic conditions at Network Rail facilities.
- ***Use Case 2 – Stationing and maintenance***
  - Monitoring: monitoring of current/voltage/environmental conditions
- ***Use case 3 - Electrical Infrastructure Monitoring***
  - Detection of electrical anomalies (IN-OP) on London North Western (LNW), a line between London Euston station and Scotland









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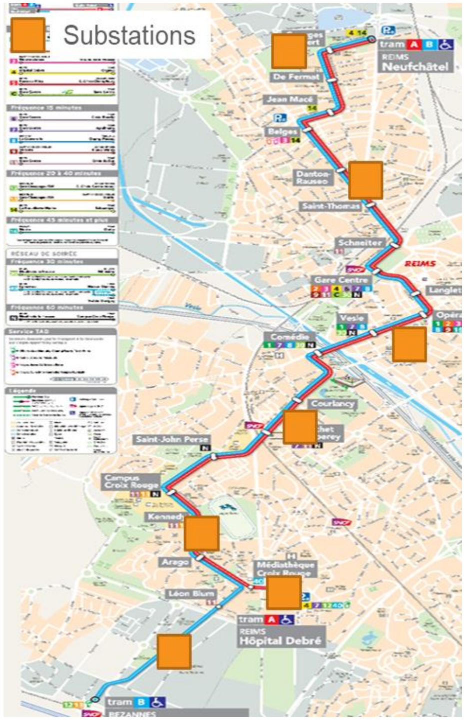
Techno-economic evaluation

- Techno-economic analysis following the techno economic assessment (TEA) methodology considering both ***capital*** and ***operational*** expenditures
- Identification of deployment and operational costs based on the REIMS tramway experience covering
  - Monitoring equipment: Sensors
  - Network devices: LTE, LiFi, WiFi, Gateways etc
  - Processing resources: CPU, RAM
- Benefits for the operators related to
  - Energy billing
  - System level Optimization
  - Preventive maintenance



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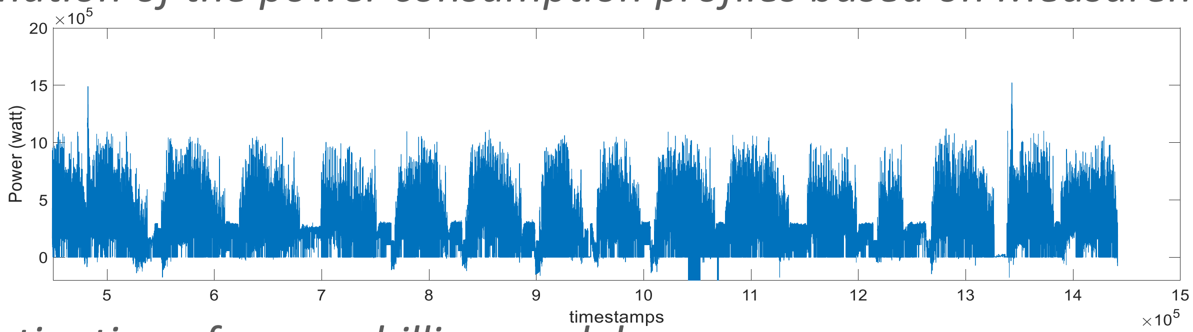
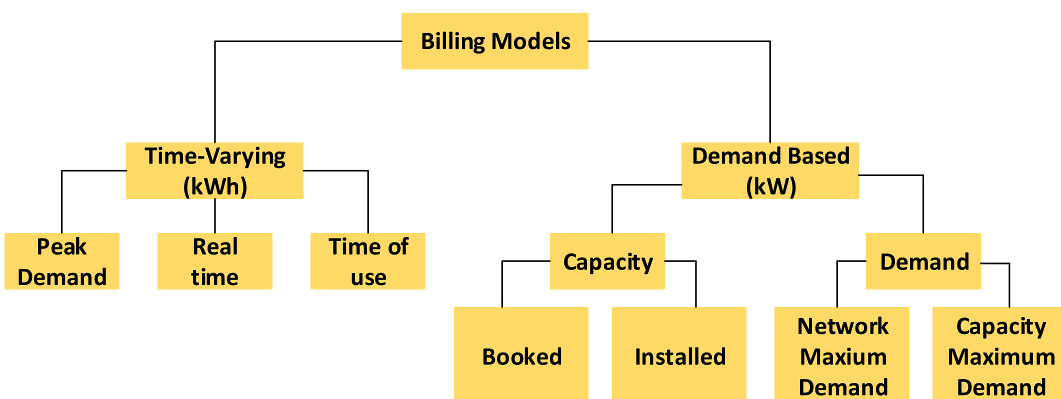
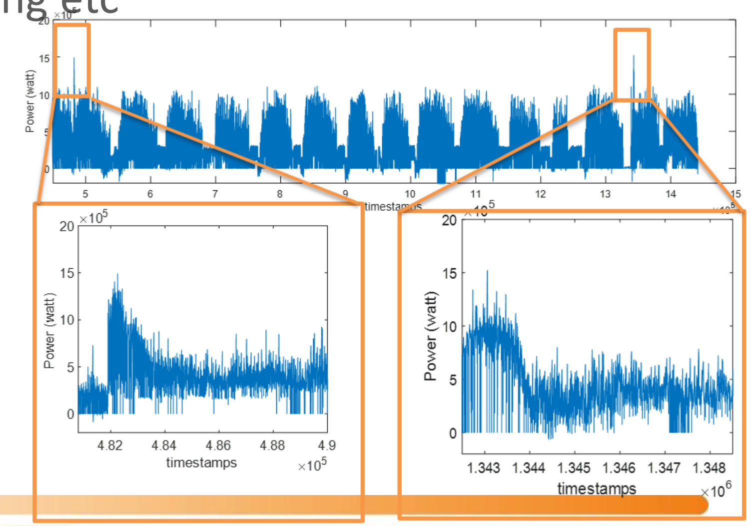
IN2DREAMS Technical economic evaluation

- *Step 1: Identification of the costs for the Monitoring, Telecom and Processing Equipment*
- *Step 2: Estimation of the power consumption profiles based on Measurements*



- *Step 3: Investigation of energy billing models*
  - Models considering peak events, half-hour billing etc





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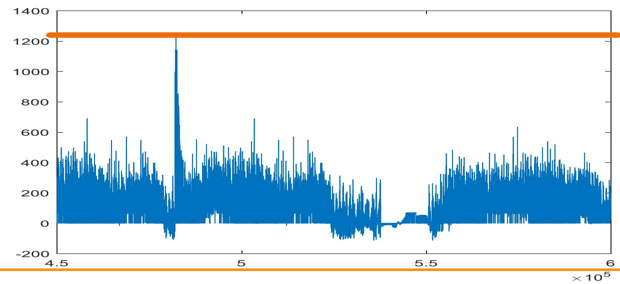
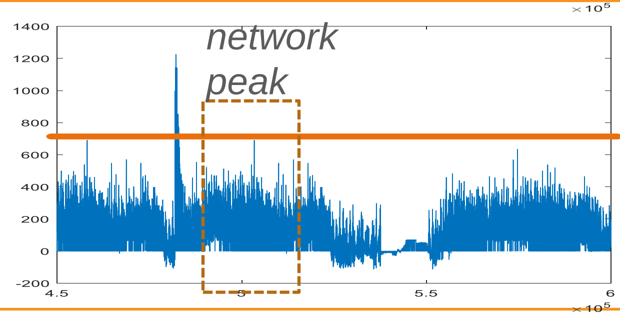
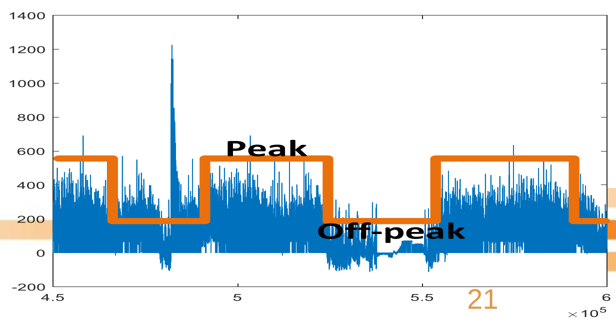
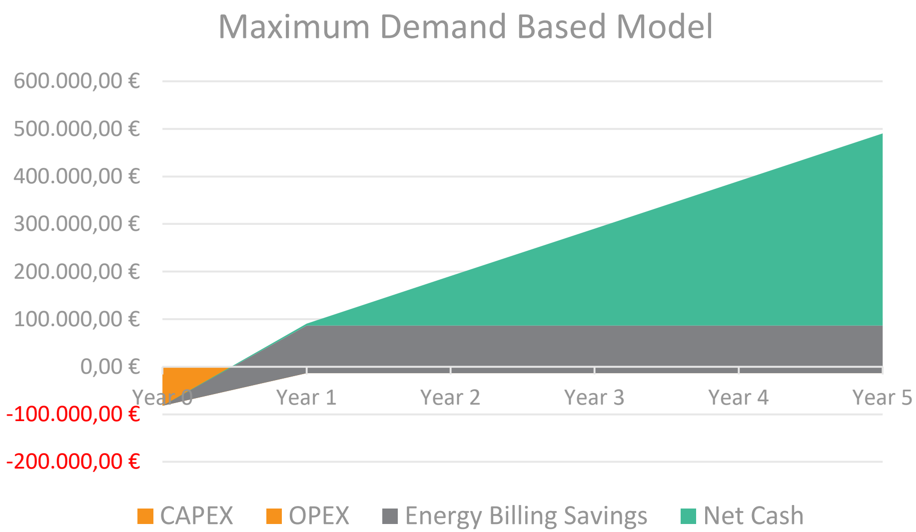
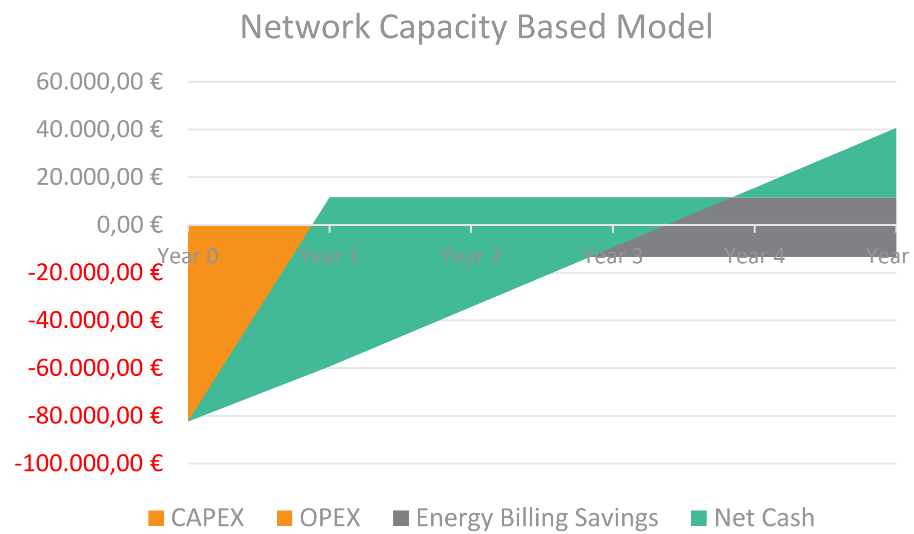
Techno-economic evaluation

- *Step 4: Quantifying energy savings under various power supply models*

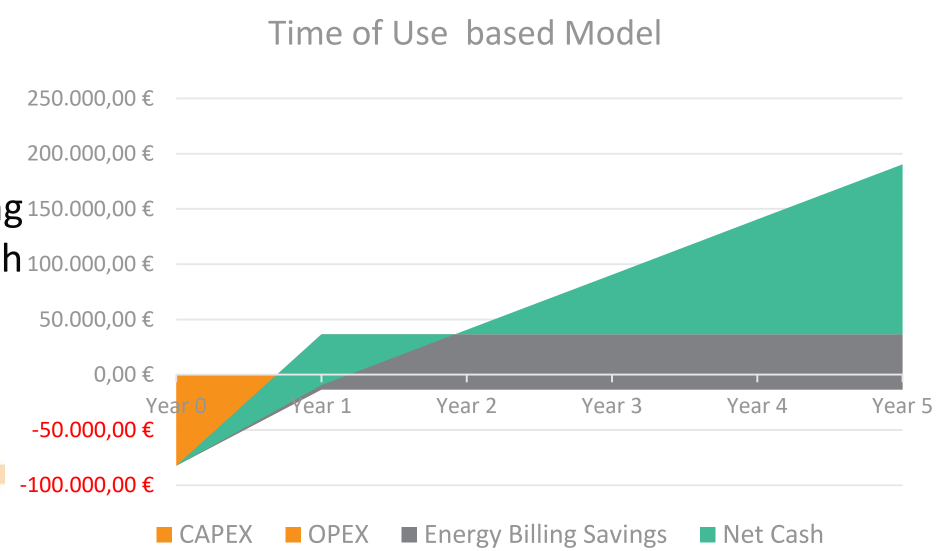
Type of energy billing	Load Profile at REIMS (blue) and billing policy (orange)	Effects on load by the proposed scheme
Fixed (maximum demand based)		• Cost reduction as the maximum demands will be reduced. • Energy cost reduction: 40%.
Network Capacity (maximum demand based)		• Cost reduction as the maximum demand at network peak can be reduced. • Energy cost reduction: 10%-20%.
Time of Use		• Cost reduction due to load shifting. • Energy Cost reduction: 10-20%

Net Cash Flow Analysis





high €/KWh during peak hours, low €/KWh during off-peak



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T2.2 On-board network

Goal: Deployment of a multi-technology on-board wireless access system
Partners: PURELIFI, UNIVBRIS, IASA, DOTVISION

- *Deployment of a multi-technology wireless access system based on the integration of heterogeneous WiFi/LiFi and LTE systems. On-board installation of*
  - commercially available devices Teltonica routers providing WiFi/LTE connectivity
  - Purposely developed Gateways by DotVIsion providing WiFi/LTE connectivity
  - Extensive experimentation with open source LTE platforms
  - Lab validation of LiFi technology
- *Planning and dimensioning studies to identify the optimal mix of WiFi/LiFi and LTE technologies*
  - Planning model based on Integer Linear Programming (ILP)
  - Sensitivity and reliability analysis.

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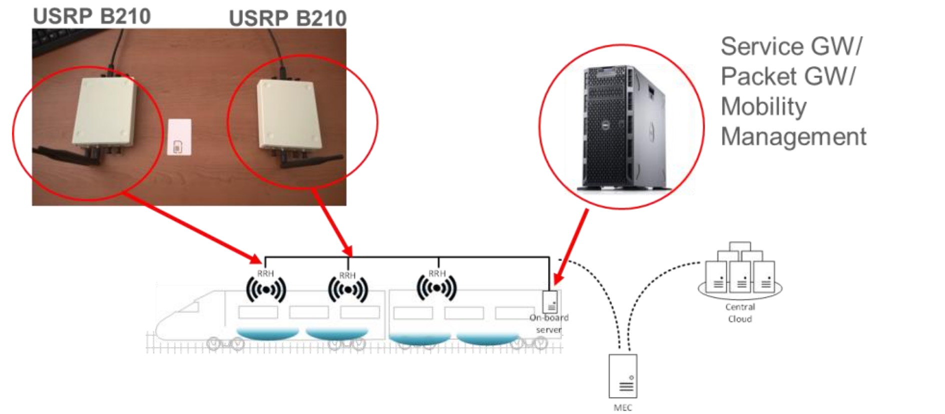
T2.2 On-board network

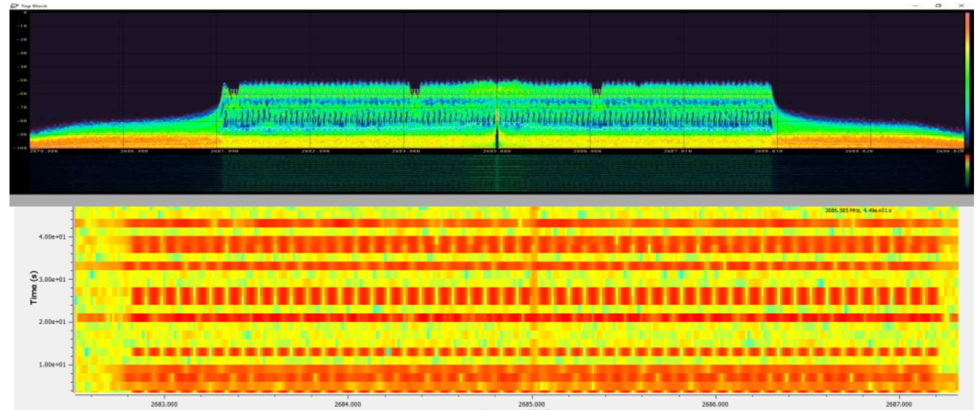
- *Open Source LTE Platform*
  - *Based on OpenAirInterface*
  - *Remote Antennas based on Ettus USRPs*



- *LTE Platform: Performance Evaluation*
  - Downlink up to 20Mbps for 5MHz bandwidth
  - Uplink 5Mbps
  - Resource allocation

Spectrum

Time



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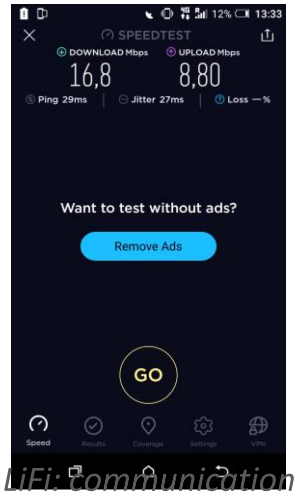
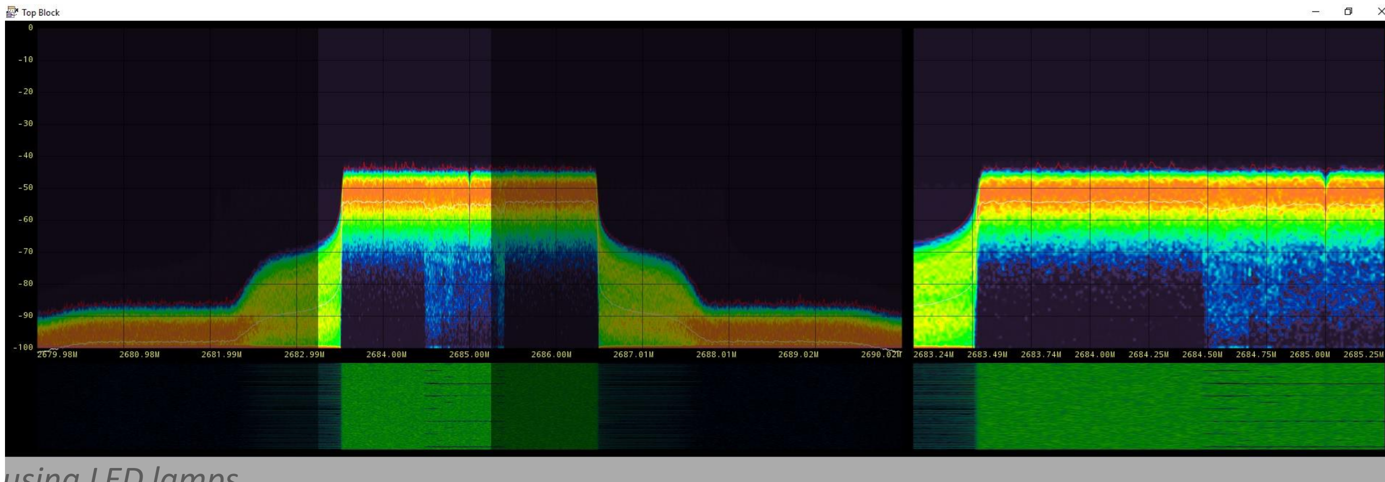
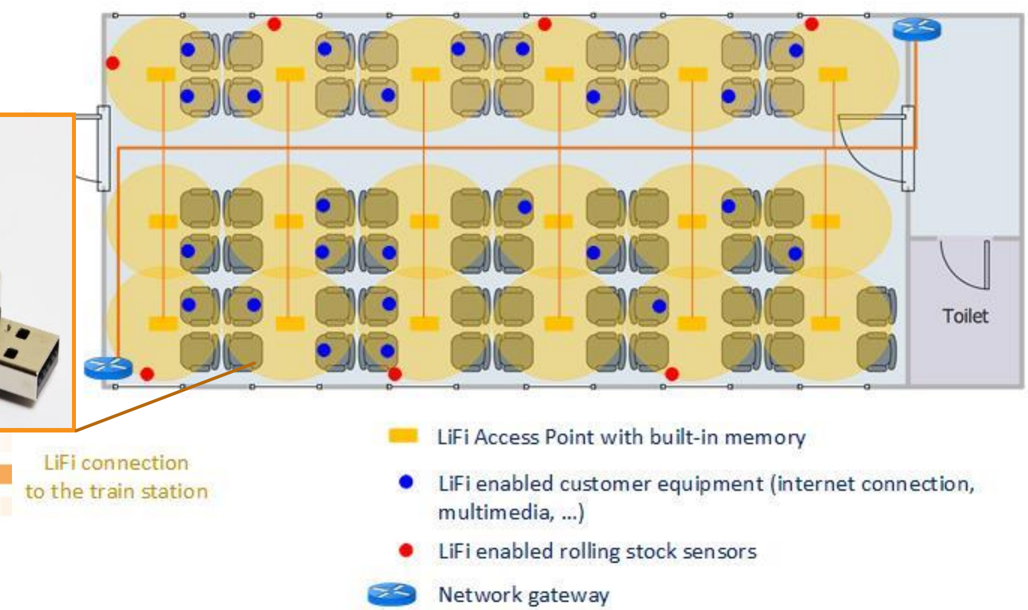
T2.2 On-board network

- *Open source LTE: Speed tests on mobile devices*





- *LiFi: communication using LED lamps*



Dimensioning Studies

Goal: Optimal Mix of WiFi/LTE and LiFi technologies aiming at identifying a cost-effective implementation for the on-board communication platform

- Modeling framework based on Integer Linear Programming
- Identify the optimal placement of the various access points so that operational and capital expenditures are minimized subject to demand and capacity constraints

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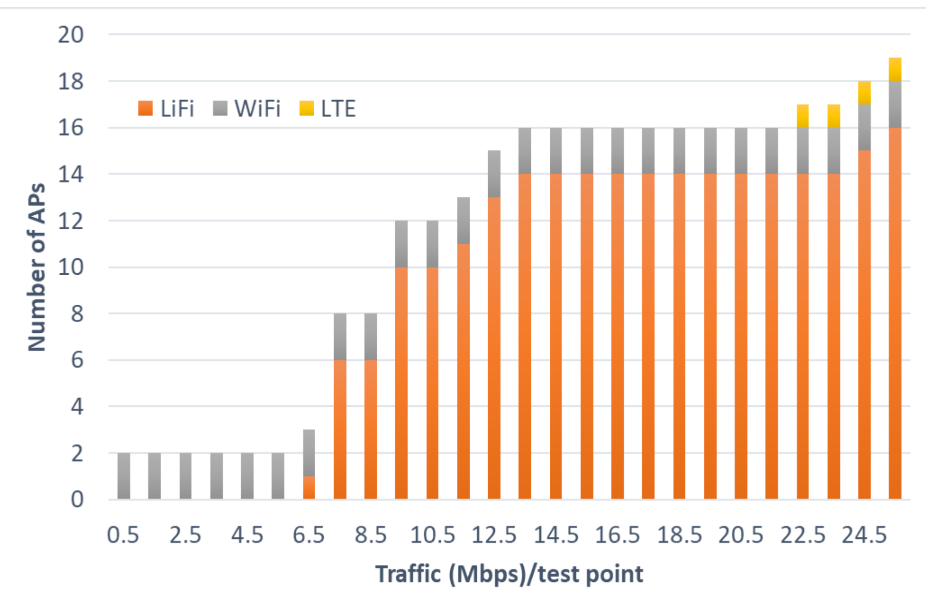
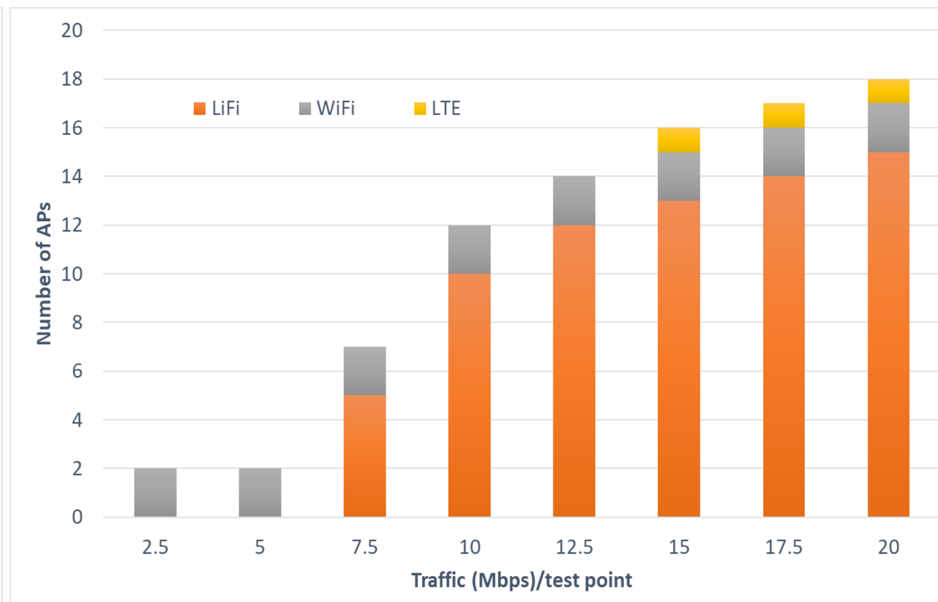
- Objective function: Minimize the overall operational plus capital expenditures of the combined solution

$$\min \left[\sum_{j\in\mathcal{S}_{LTE}} \mathcal{C}_j^{LTE} y_j^{LTE} + \sum_{j\in\mathcal{S}_{LF}} \mathcal{C}_j^{LF} y_j^{LF} + \sum_{j\in\mathcal{S}_{LF}} \mathcal{C}_j^{WF} y_j^{WF} \right] + \sum_{i\in\mathcal{P}} \mathcal{D}_i \left[\sum_{j\in\mathcal{S}_{LTE}} \mathcal{E}_{ij}^{LTE} x_{ij}^{LTE} + \sum_{j\in\mathcal{S}_{LF}} \mathcal{E}_{ij}^{LF} x_{ij}^{LF} + \sum_{j\in\mathcal{S}_{LF}} \mathcal{E}_{ij}^{WF} x_{ij}^{WF} \right]$$

- Subject to access traffic and capacity constraints (Anastasopoulos et al., TRA 2020)





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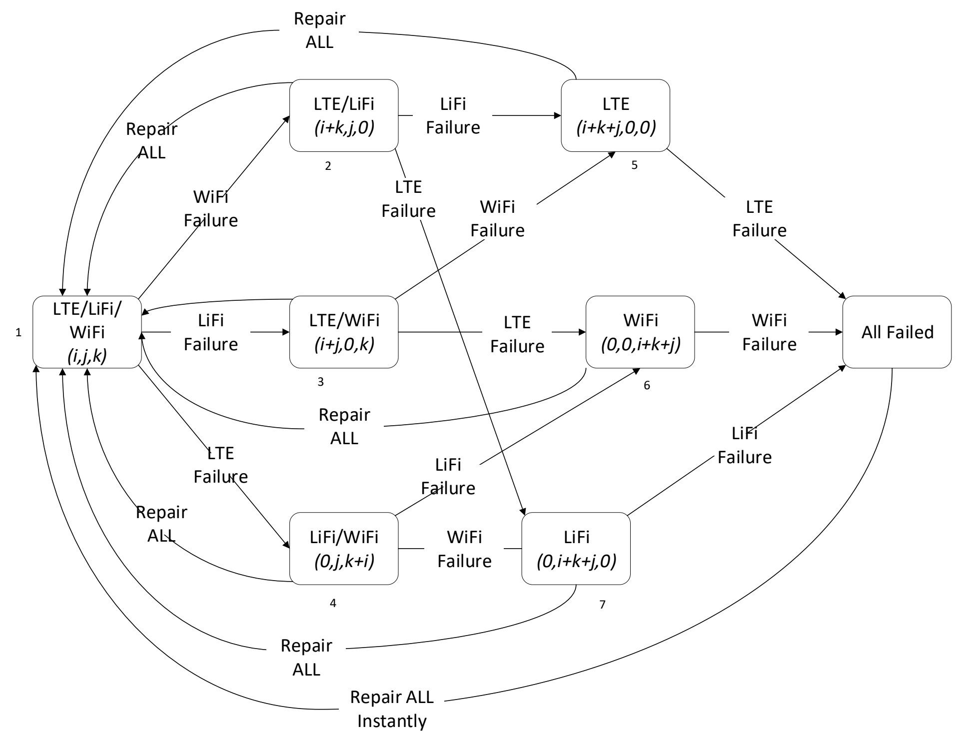
Reliability Analysis

- *Benefits of the combined solution:*
  - Improved Capacity
  - Improved resilience
- *Theoretical evaluation based on Markov Chain Analysis*

Repair/failure transition states of the on-board multi-technology access network comprising LTE/LiFi/Wi-Fi



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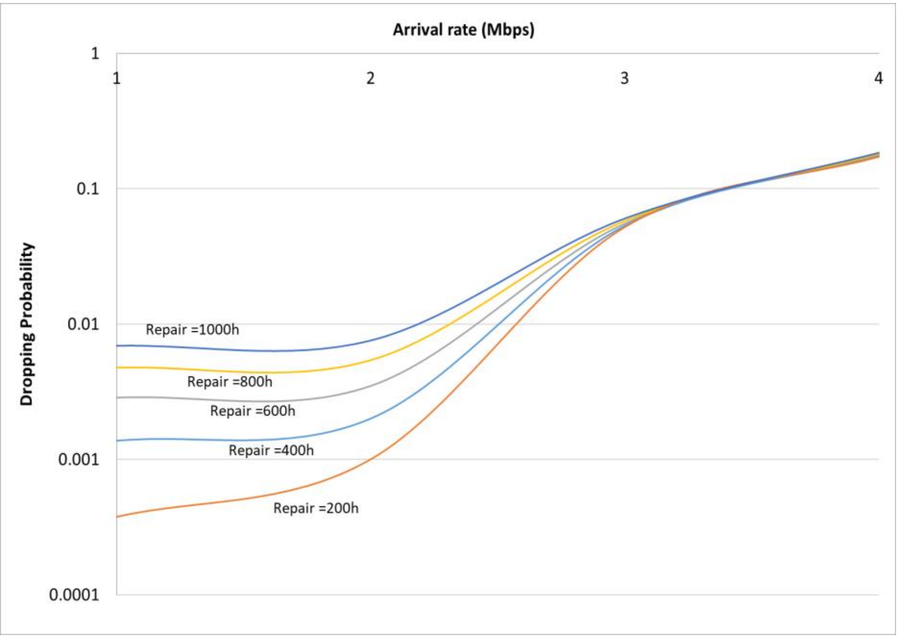
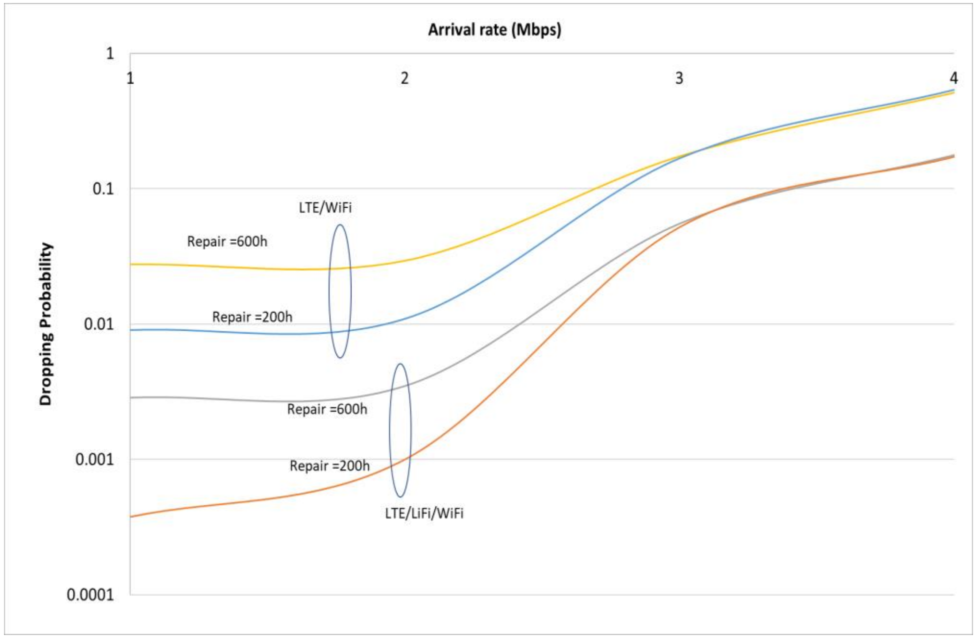
Numerical results





LTE/WiFI/Lifi

LTE/WiFI/LiFi vs LTE/WiFi

Dropping probability as a function of the arrival rate per AP for various repair time intervals

IN2DREAMS T2.3 Trackside to Control Centre

Goal: Development of the ground to operations control Centre network infrastructure
Partners: UNIVBRIS, IASA, DOTVISION

- ***Data Plane Technologies***
  - Wired Optical
  - Standard Electrical
- ***Alternative Communication Bearers:***
  - Free Space Optical (FSO) Communication providing trackside connectivity
- ***Control Plane***
  - *Adopting the Software Defined Networking paradigm*

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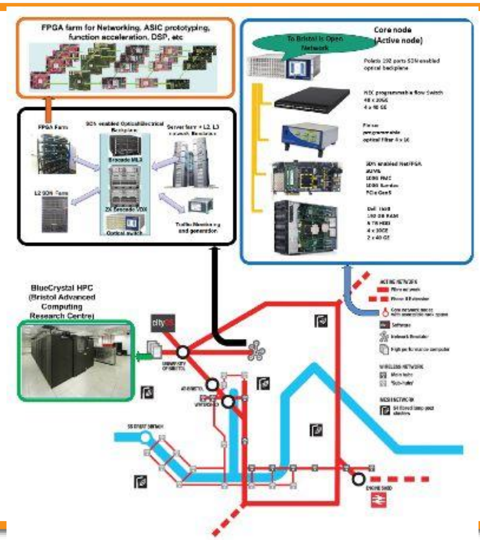
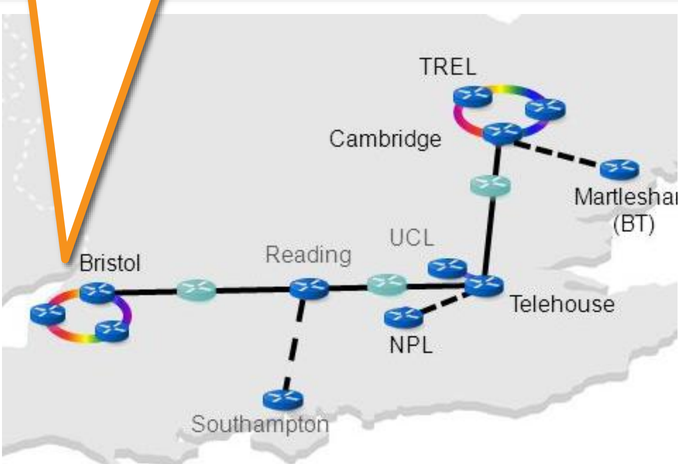
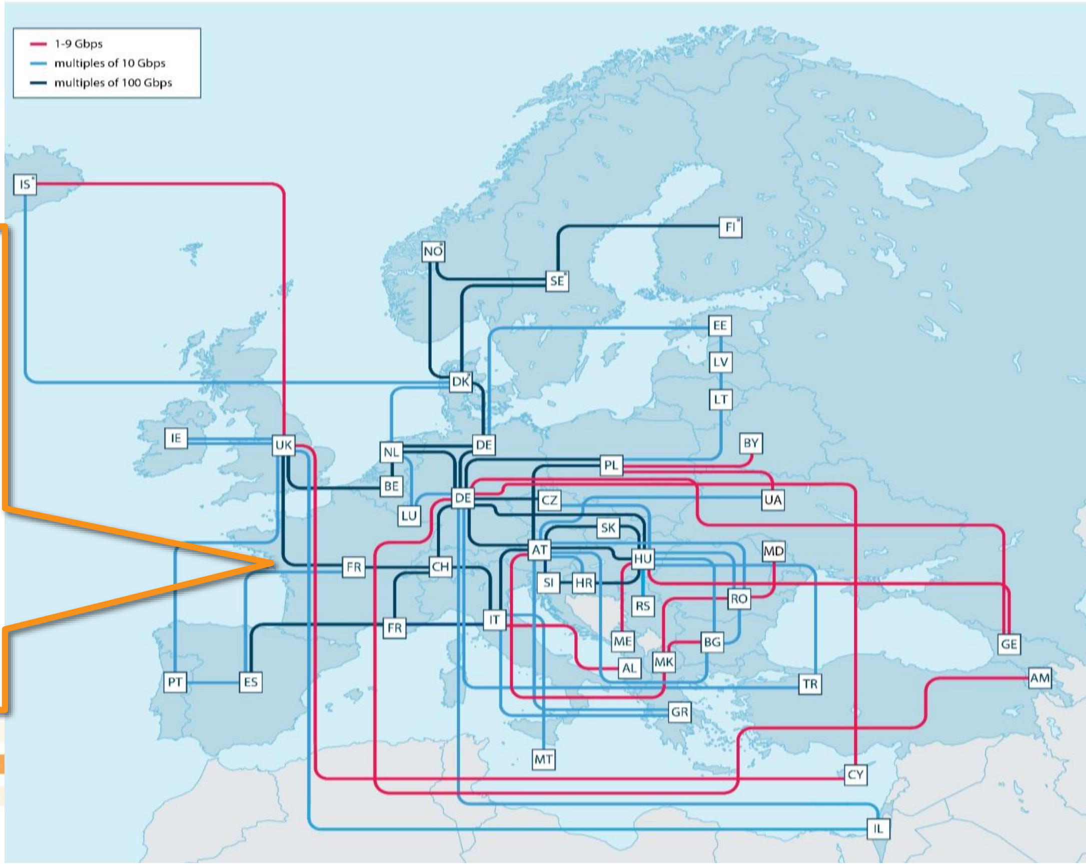
Wired Optical Network technologies



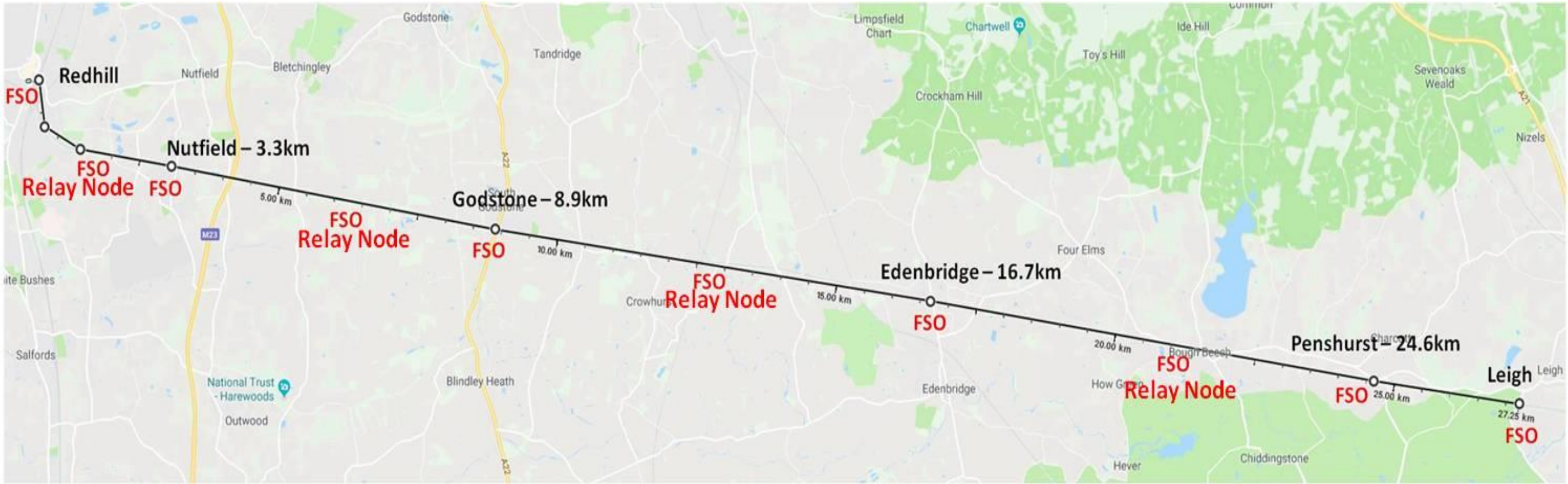


- Access to GEANT through IASA & UNIBRIS
- Access to NDIFS through UNIBRIS



FSO Technical Specifications

- ***Use of FSO systems for Ground to Ground communications between train stations***



Communication Coverage of railway network between Redhill and Leigh using FSO systems

Advantages of FSO systems

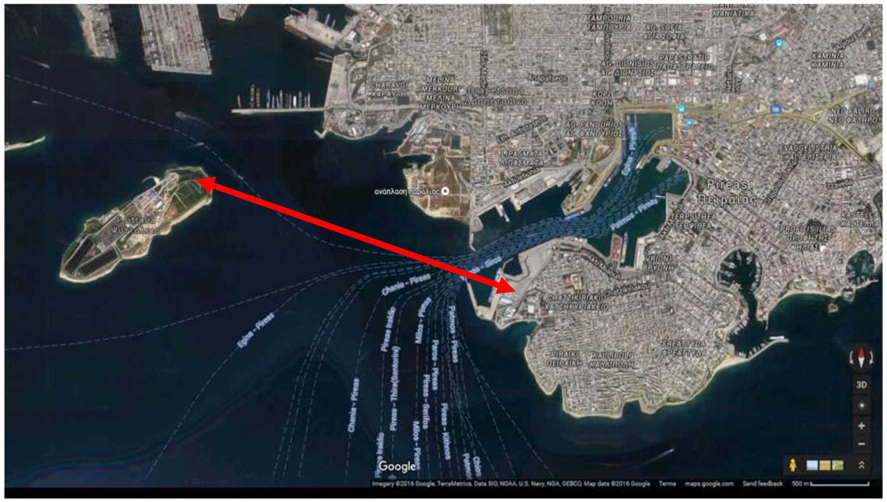
- *High Performance, reliability and availability (1.25Gbps up to 10Gbps – Availability up to five 9's)*
- *Low Cost*
- *High Security Level*
- *Low Power consumption*

Flat area that is ideal for point to point FSO communication

Limitation: FSO systems are affected by various atmospheric phenomena (e.g. turbulence) and weather conditions (mostly by fog)

Validation and Experimental Data

- ***Deployment of an FSO system for research purposes in the city of Piraeus, Greece***



- Link Length: 3km
- Total Power Consumption: 22W
- Total output power (3 LASER beams): 100mW
- Wavelength: 830nm-860nm
- Data Protocol: Fast Ethernet, ATM, OC3, STM1, E3, T3, OC1/STM0
- Bit Rate: 100Mbps
- Bit Error Rate: Less than 10-12 (unfaded)

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System Installation

FSO transceiver

FSO Panel

Management Interface

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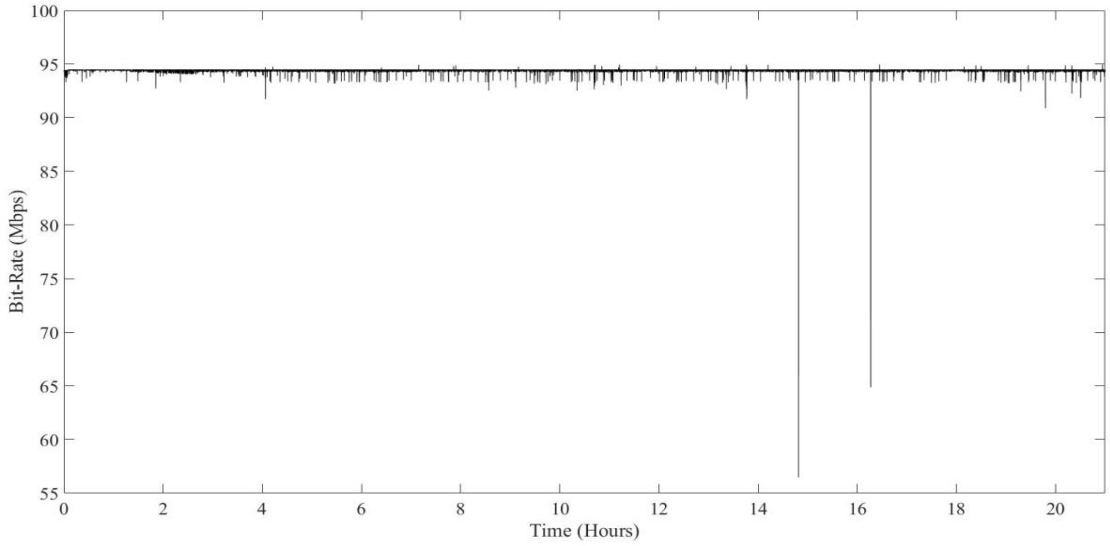
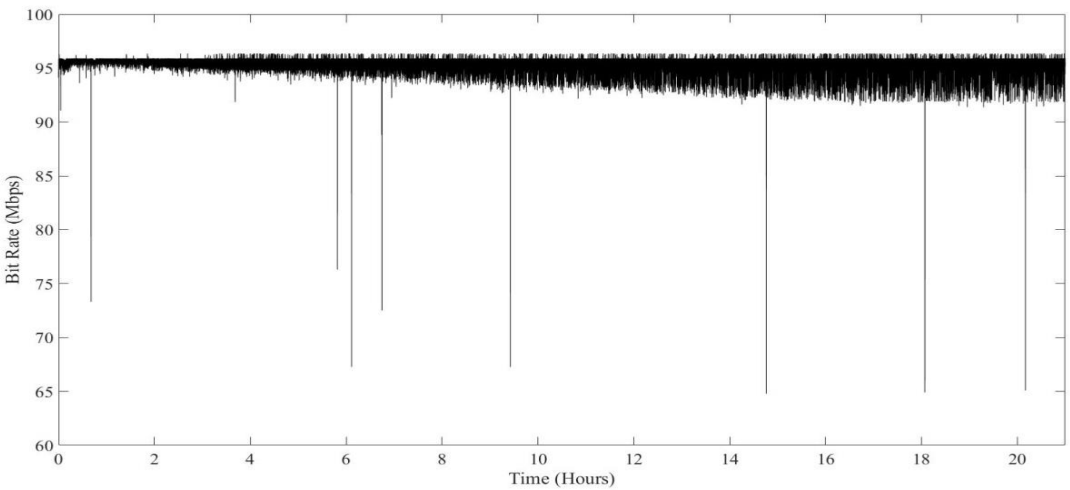
Experimental Results



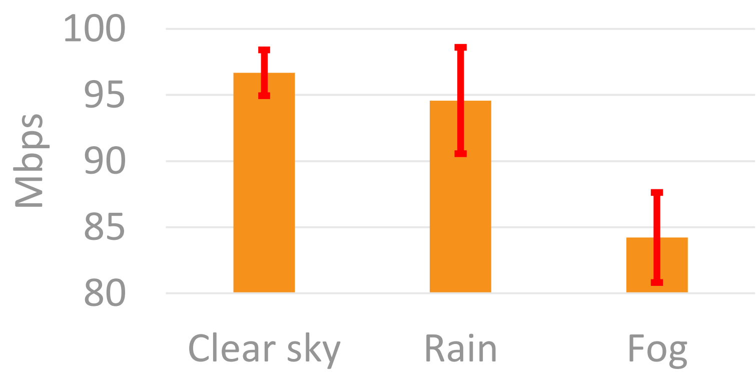
Bit-rate in a typical day of March



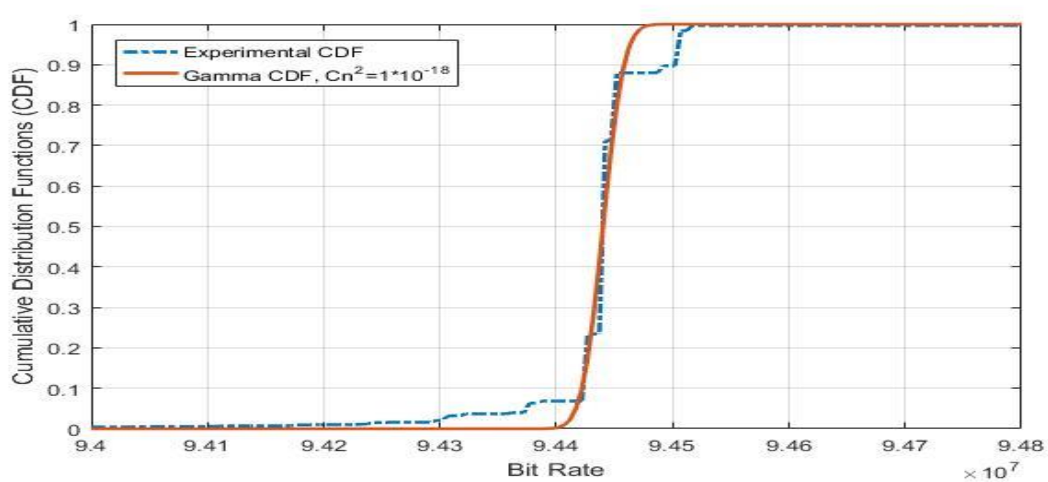
Bit-rate in a typical day of June
Wind and low humidity causes bit rate fluctuations

Experimental Results

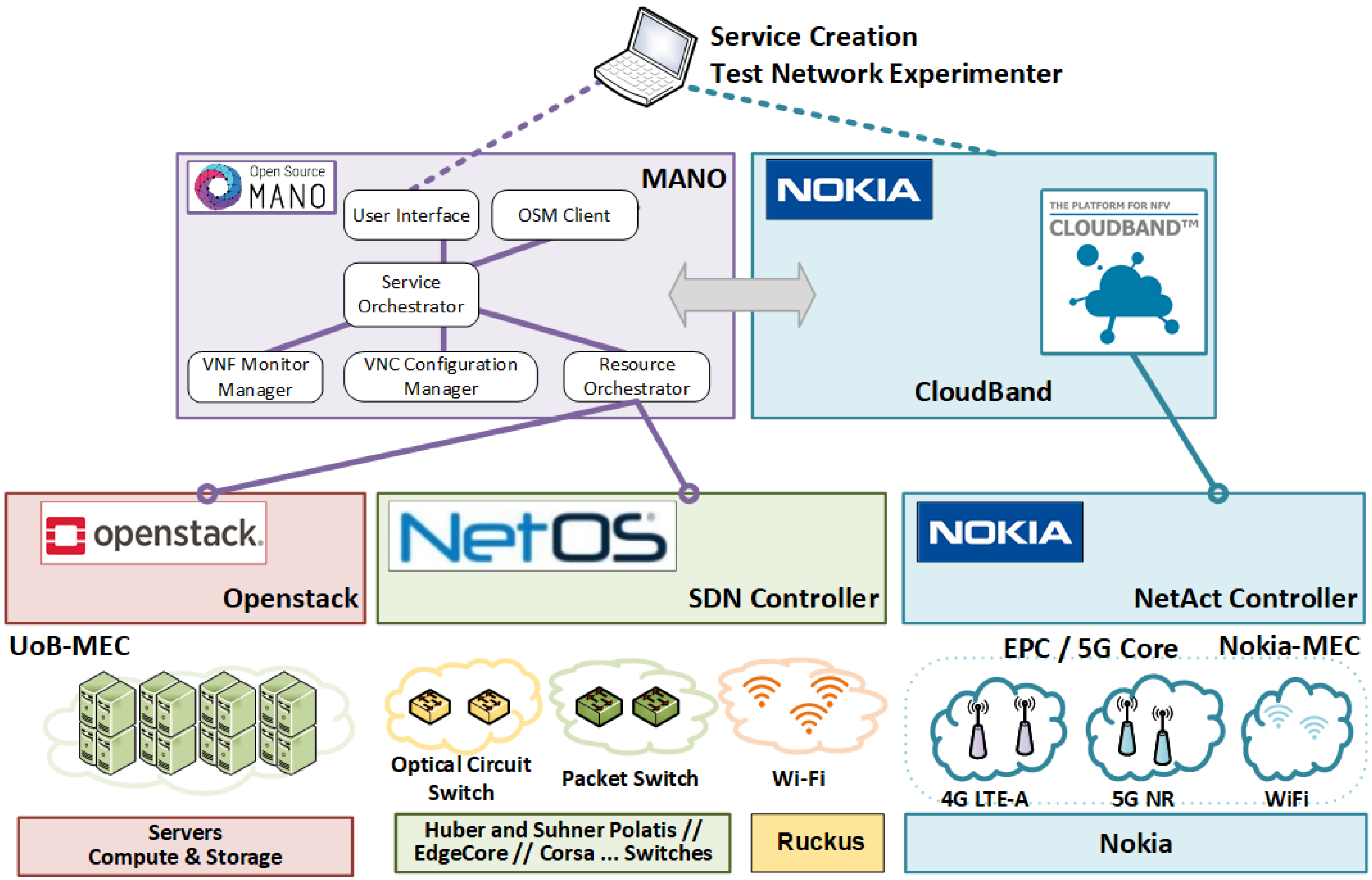
- The FSO system presents high performance with high bit rate and rare outages
- Dependence of FSO system on weather conditions



- Various theoretical Models that describe the effect of turbulence on the performance of an FSO system where verified using experimental Data.



Control Plane



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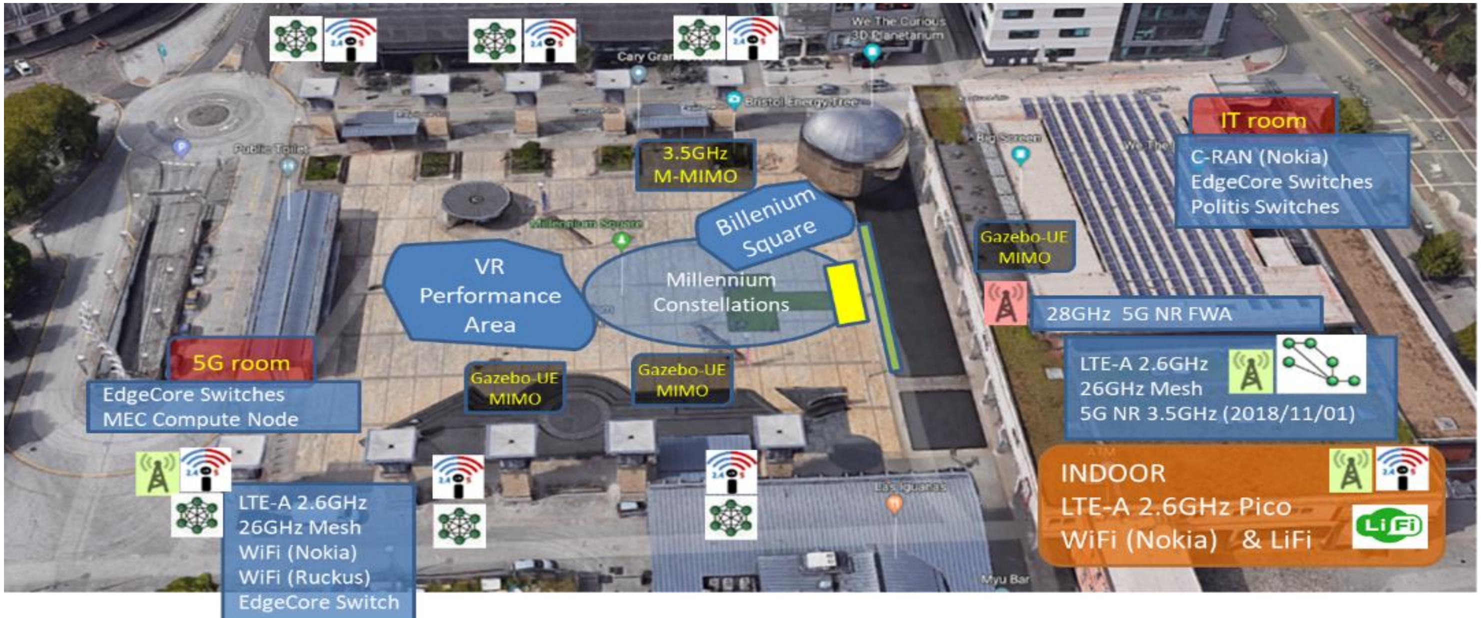
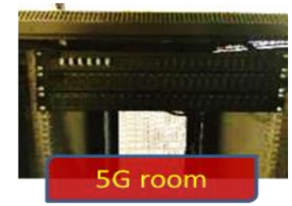
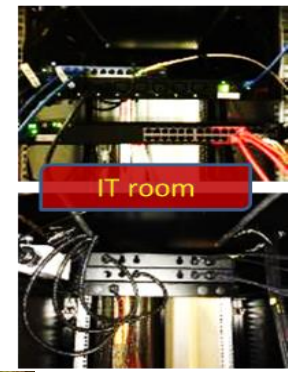
Complete Solution @ Bristol

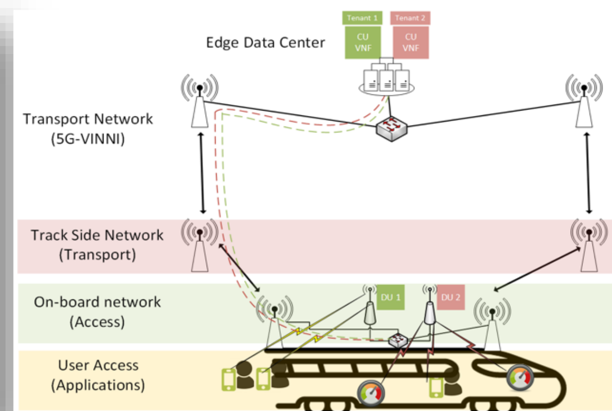






Next steps and Large-Scale Demos

- **Enhanced mobile broadband under high speed mobility in Rail environments**
  - eMBB functionality through heterogeneous technology access for on-board network connectivity in a railway setup
  - Interconnection of on-board devices with the trackside and the trackside with the core network



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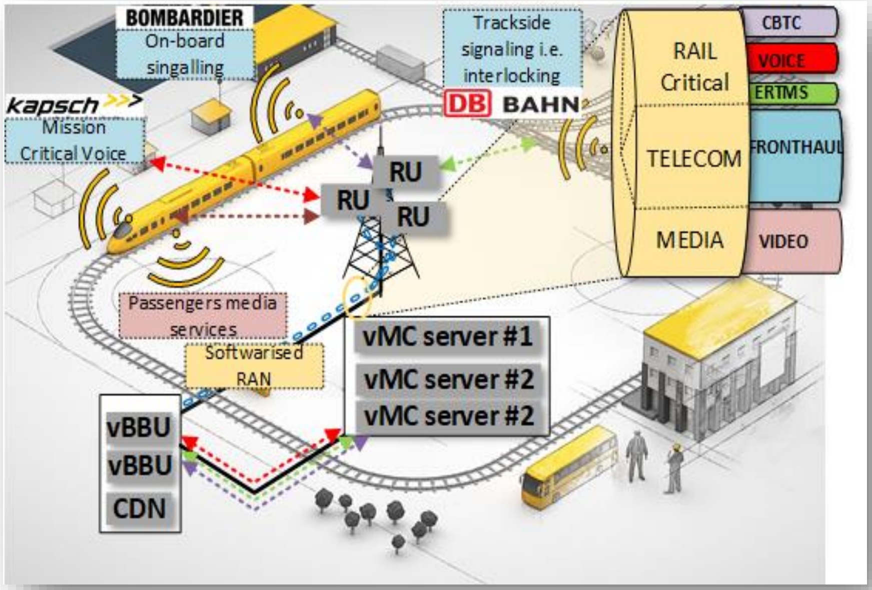
IN2DREAMS Next steps and Large-Scale Demos

- **Objective**: common platform for Mission Critical (MC) voice and video and other MC rail-related data and signalling services addressing on-board and trackside elements.
    - a softwarized end-to-end MC services solution that will enable the enhanced support of railway specific services
    - A softwarized MC solution for rail environments enabling control and management of the on-board elements and trackside compo (i.e. interlockings)



Shift2Rail

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IN2DREAMS

Sensing/Monitoring Devices and Data Management Platform

GUILLAUME PELLETIER (DOTVISION)

IN2DREAMS Final Conference, Milan, 02.10.2019

WP3 Goals – Design - Solutions

Just for the sake of understanding, WP3 is all about Monitoring and IIOT (which is industrial IOT, a sub part of the Internet Of Things bubble).

Monitoring is about how to gather data from the railway system, on board and on track, in order to evaluate the behavior of the system, using different types of computing resources and processes, from big data to AI.

Monitoring is often associated with Control, ***BUT THIS IS NOT*** *the case here and we pay huge attention of the system isolation to avoid any security breach.*

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WP3 - Goals

Goals has been set during the previous In2Rail Project.

- Data synchronisation
- Real time
- On board monitoring
- On track monitoring

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WP3 - Features

Few Compelling and/or mandatory features were defined:

- Secure;
- Low latency;
- Cost effective;
- Less intrusive;
- Low energy signature;
- Interoperability;
- W3C-oriented to enable Easiest Cloud and process integration.

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WP3 – Design

For this purpose, we designed a full IIOT Stack solution, from Hardware (with a Real Time Operating System embedded) to cloud hosted solution.

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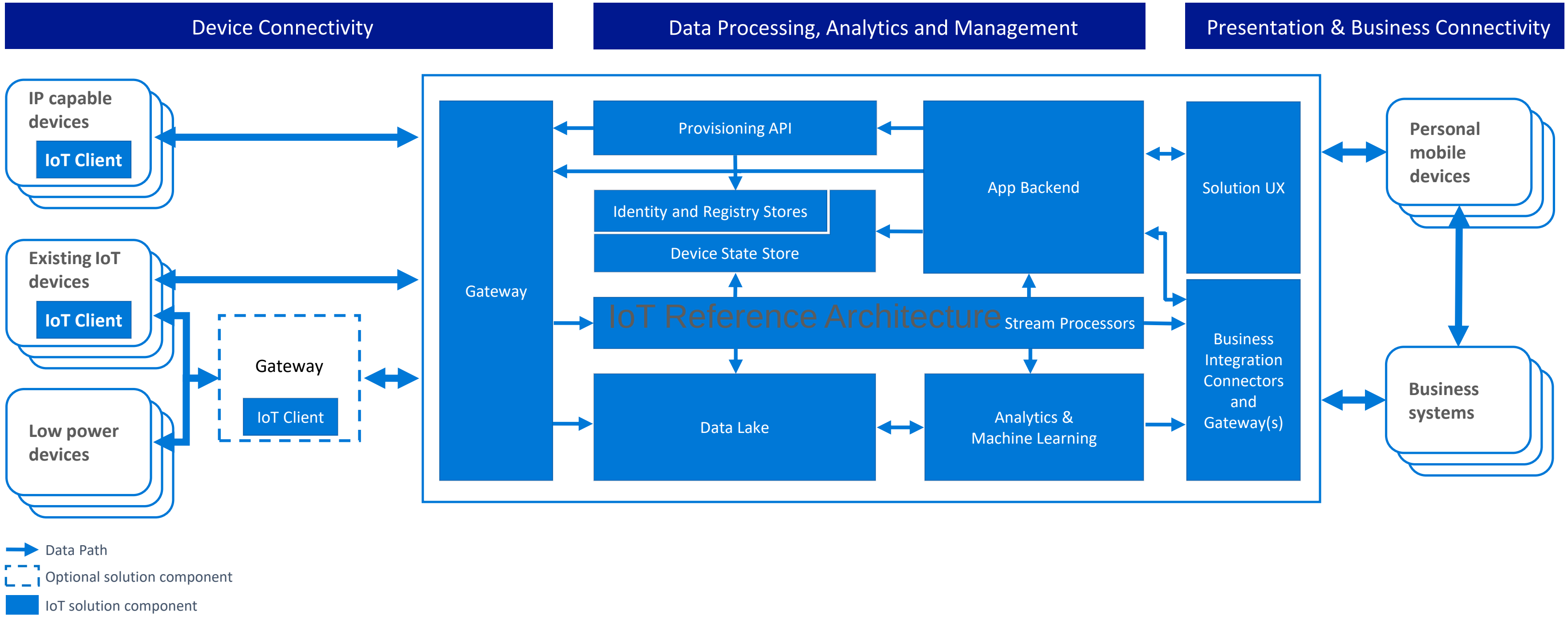
WP3 - IoT Reference Architecture



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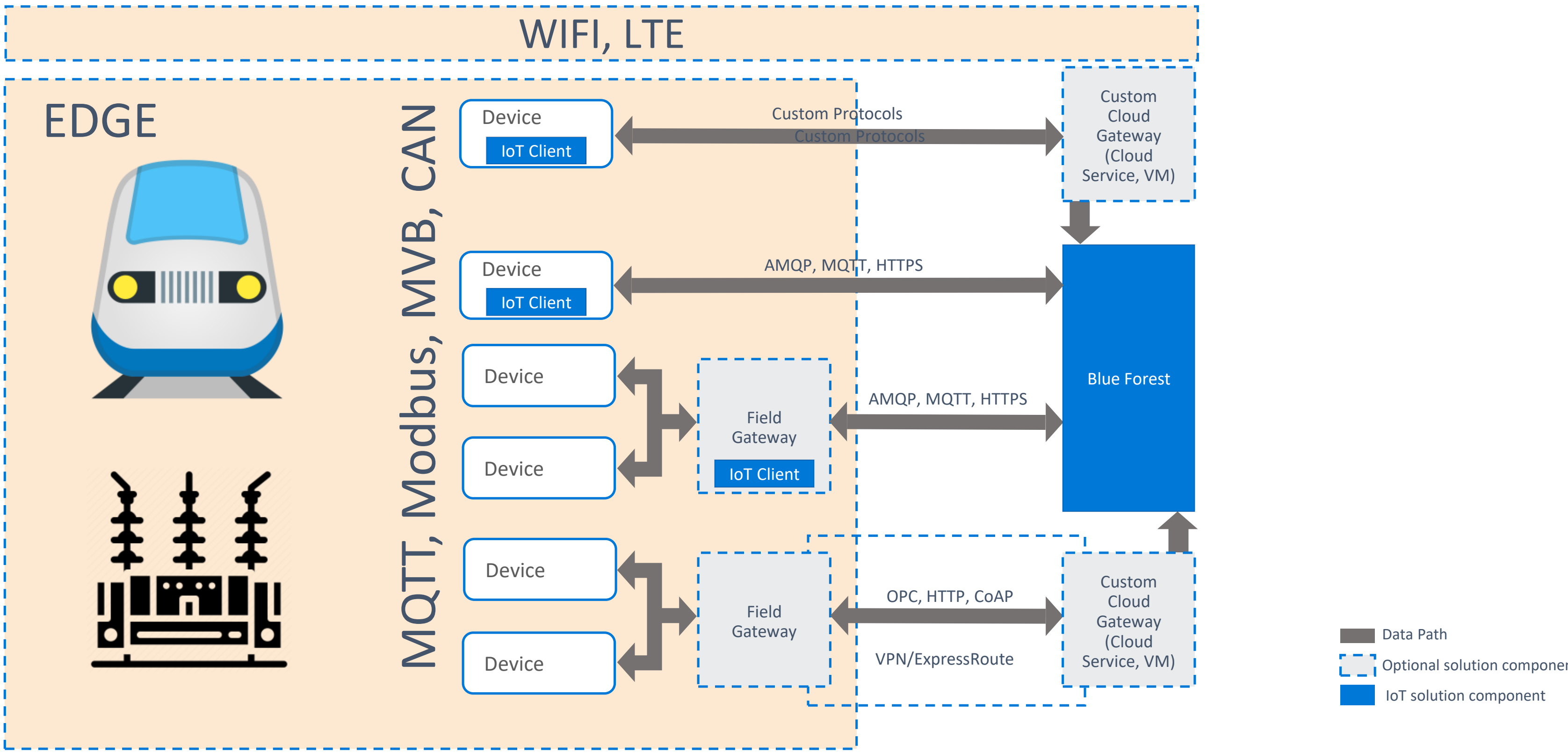
WP3 – Design

With the help of WP2, we embedded Communication solutions, From LTE to WIFI, respectively for Global and Local physical communications, using dedicated Industrial data transportation Protocol & W3C standards

WP3 -Device Connectivity Options



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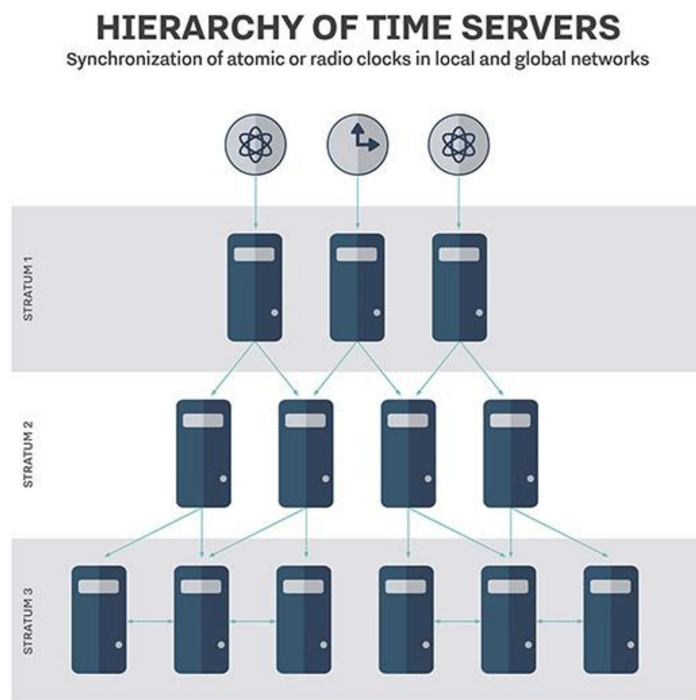
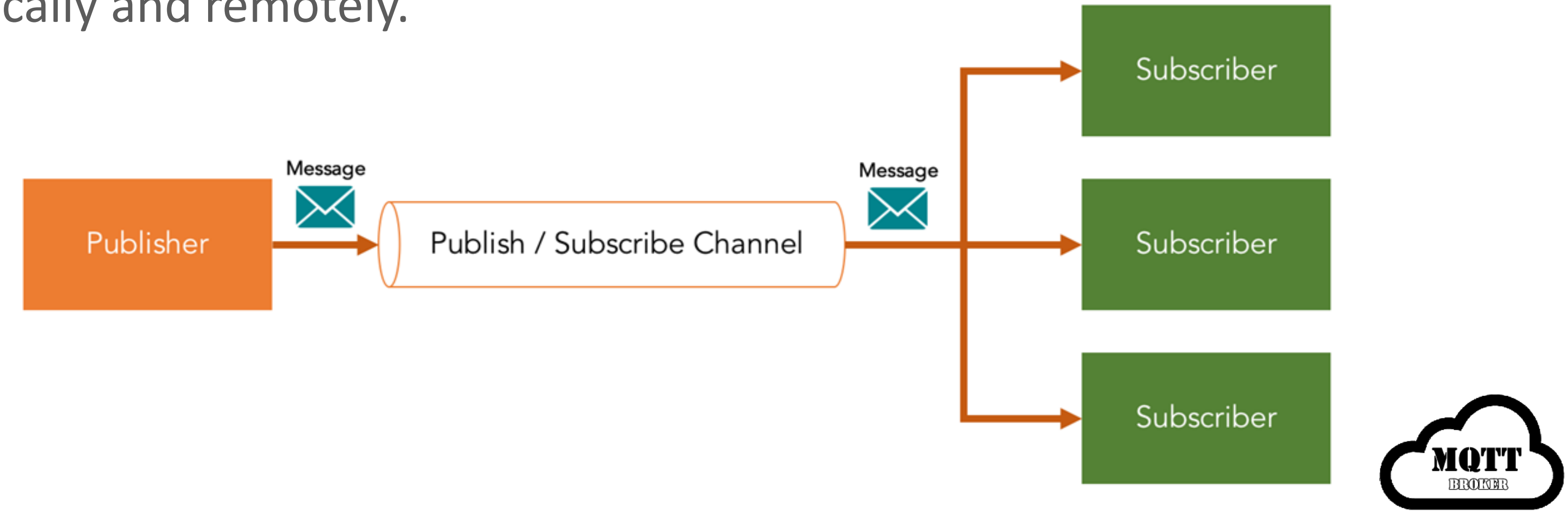
WP3 – Design – Synchronisation

Data Synchronization is supported using local NTP with a stratum 1 server embedded using GPS signal. When not available, remote NTP server could be used.



WP3 – Design - RealTime

Realtime data gathering is by design, using MQTT or SQTT protocol, locally and remotely.



WP3 - Design – On board Metering

On Board monitoring is performed using the ALOHA box, specifically designed for the purpose.

Aloha box act as global gateway, providing ALL the software and hardware stack to send data to the cloud. Aloha box support natively, TCP, TLS, LTE, WIFI and BTLE. LORA could be provided as Extension.

WP3 - Design - On board Metering

Aloha box acts as local gateway, providing ALL the software and hardware stack to transduce natively some local protocol such modbus (serial and IP) and I/O.

MVB and CAN, are provided as extension.

Once onboard, you can monitor in real time all the data from the train and equip the train with additional non-intrusive sensors at low cost.

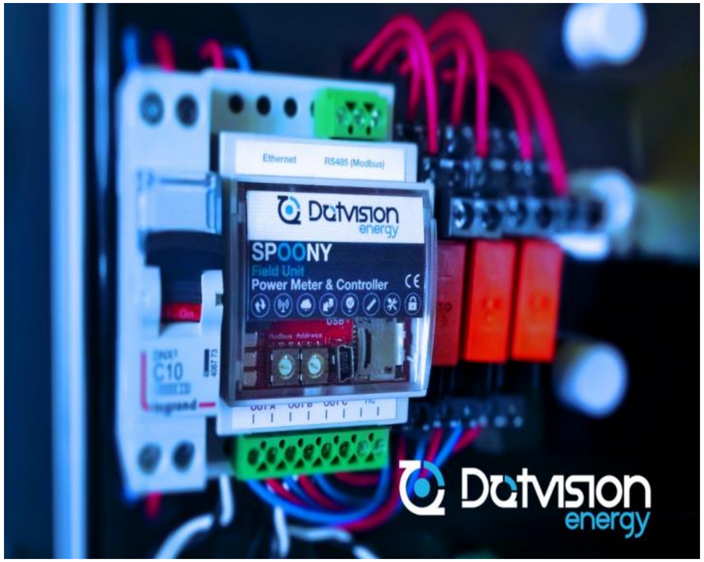
- CO_2 Sensors
- GPS
- IMU
- UV Arcs
- …

Blue Panda INSIDE

WP3 – Design – On Track Monitoring

On Track monitoring is performed also using the ALOHA box, thanks to its multipurpose and programmable I/O.

We also use SPOONY, which is a real-time 3 phasis meter.



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WP3 – Design – Tools

When hitting the cloud, the data can be stored, visualised

and analysed through WP6

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WP3 -Design - Processing - CLOUD

The data-gathering process is to serve applications and services, based upon the underlying data streams.

Available data streams are, but not limited to:

- On board consumption;
- On board dynamic (GPS and IMU);
- Specific Alarm and reports.

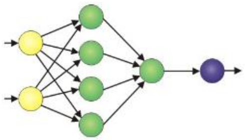
This data is clearly BIG DATA and the transport over telecommunication network hit the threshold of our LATENCY and COST features.

WP3 - Design – Processing – AI

With the Help of UNIBRI it was decided to set up an AI model to process the data.

- Using the on Board and On track consumption, coupled with GPS feature on train, to get consumption time series forecast using LSTM neural network.

- Using the on-board dynamic and consumption training set to build another model for consumption estimation using dynamic only.



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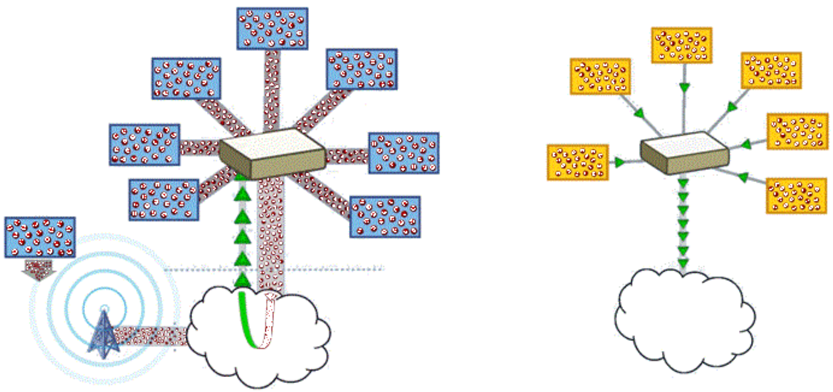
WP3 -Design – Processing - FOG

However, as stated before, the data gathering process is too heavy. It was therefore decided to promote a distribution of the AI on Edge.

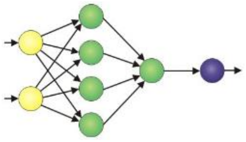
For this purpose, a specific NN library was embedded over Microcontrollers hosted by the ALOHA. Once trained, the models are provided to the edge using ONNX standard.

As result, the Cloud becomes FOG.



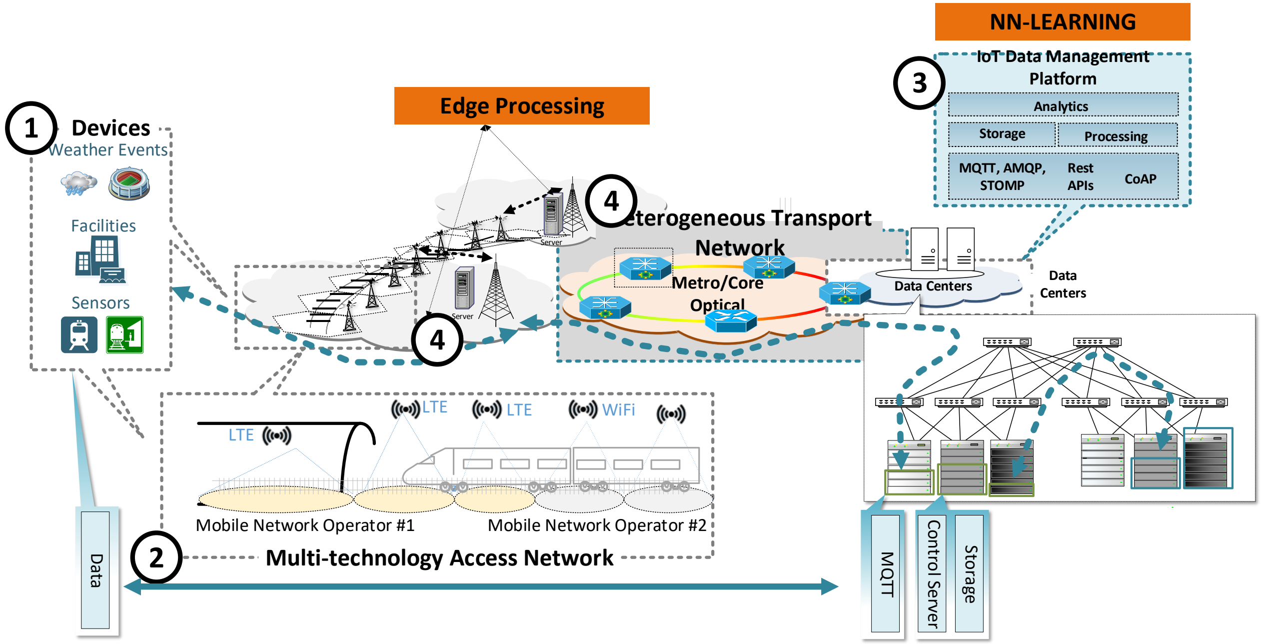
Cloud-centric AI

Edge-node AI



Use Case

- Mobile Edge Cloud (MEC) assisted Cloud Infrastructure
  - Collaborative edge-central cloud data processing → reduced latency



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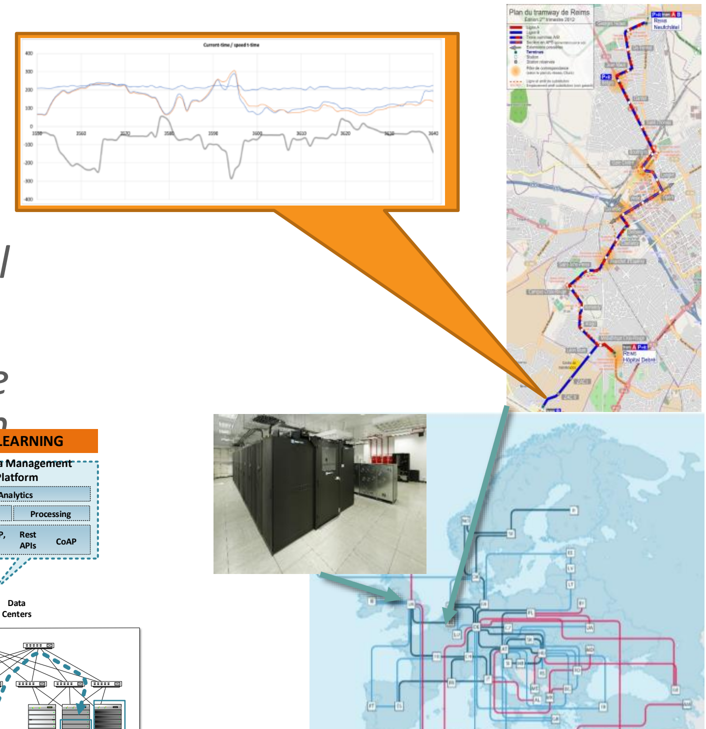
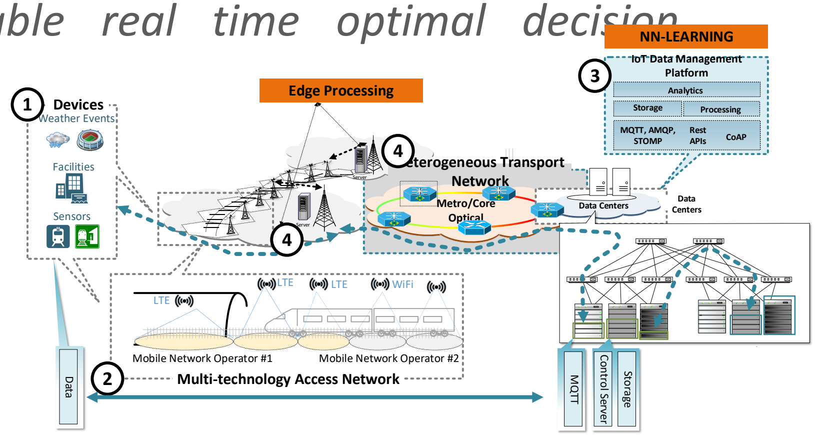
MEC-assisted applications

- **_REIMS Tramway_**
  - *Step 1: On-board and trackside data collection*
  - *Step 2: Transmission of data to the central cloud*
  - *Step 3: Knowledge extraction based on Neural Networks*
  - *Step 4: Push the trained Neural networks at the edge to enable real time optimal decision making*





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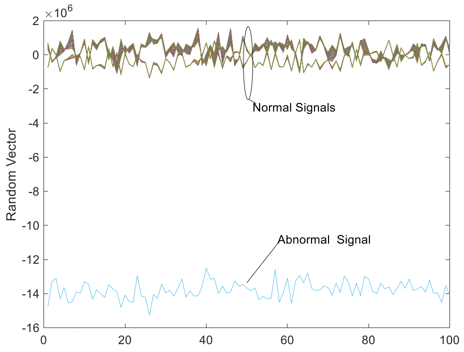
MEC-assisted applications

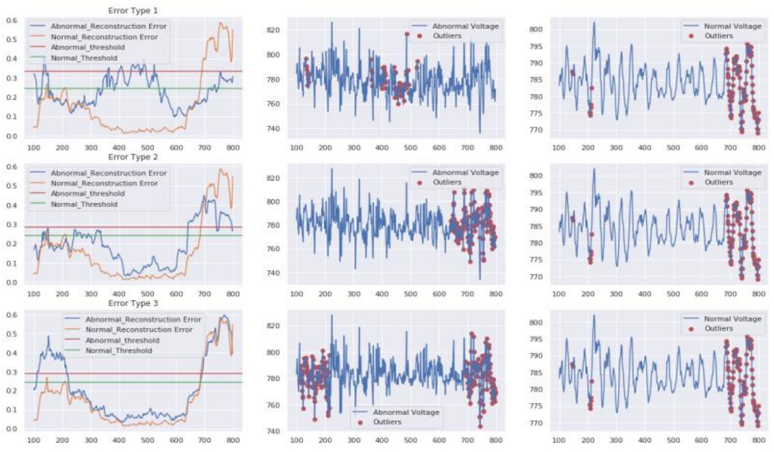
@Network Rail

- *Use case: Fault detection over high frequency sampling at substations*



@REIMS

- *Fault detection in an operational tramway system*



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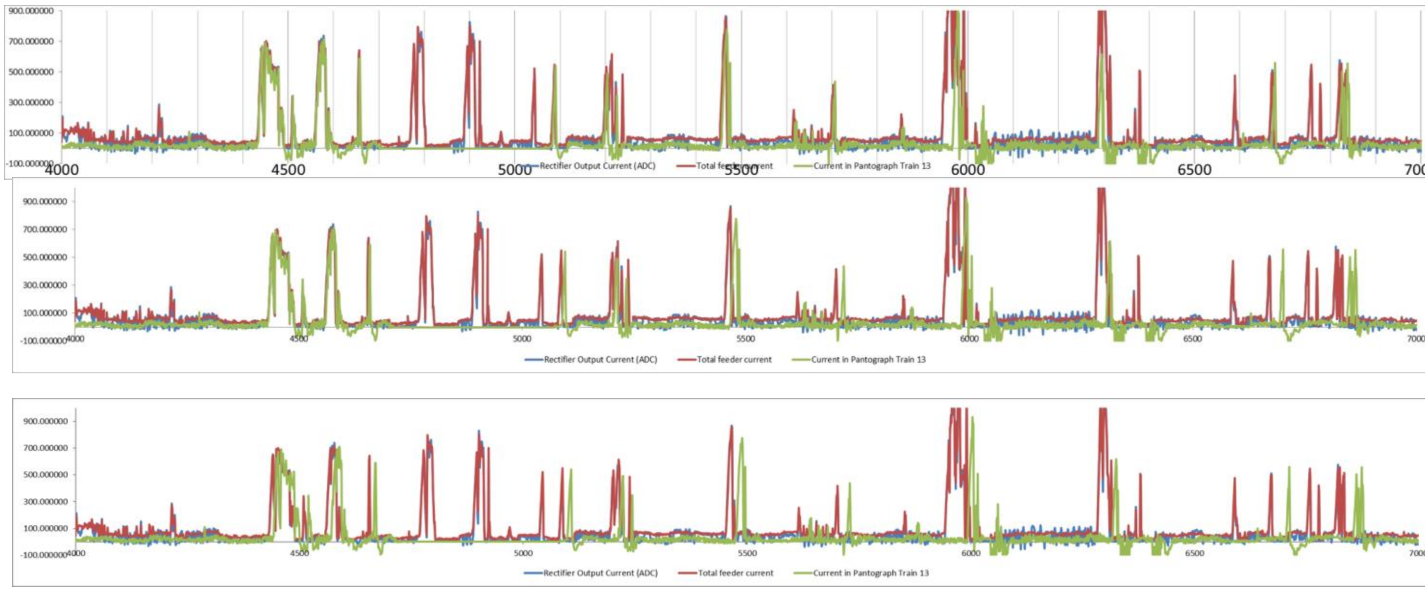
Applications

- Synchronization of measurements



- **Positioning (Without the need of GPS) using telecom network**
  - **In-tunnel positioning using LiFi**

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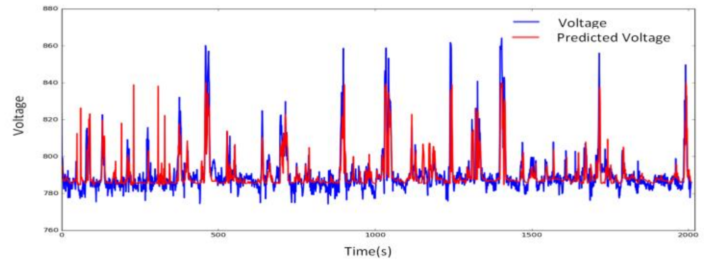
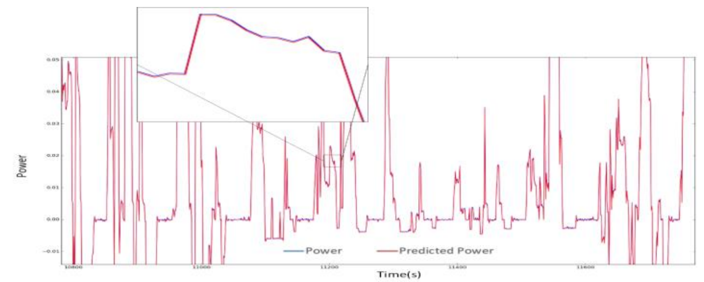
Applications

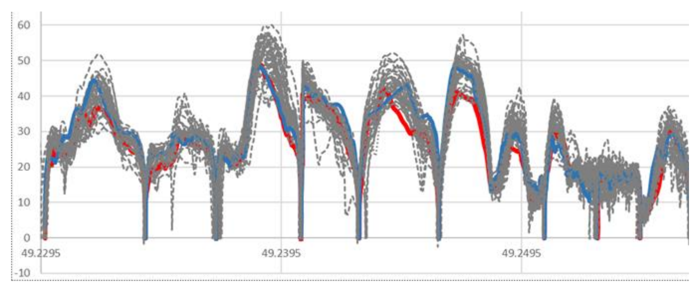
- Estimation of trackside from on-boar measurements (software sensors using purpose developed NN models)



- Energy forecasting using LSTM NNs



- Optimization (optimal driving profiles) (using Machine learning Techniques)



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WP3 - Results

- The global monitoring chain is working as TRL 8 and 9, AI process are still on TRL 6,7.
- The solution was installed on the Reims Tramway.
- The on-track solution was installed at 3 NR sub-stations near London.
- These installations are being duplicated in Zaragoza and Dublin.

IN2DREAMS

WP3 – Next steps

- First, we have now to finalise and promote the Hardware/Software solution as real world Industrial product and we are looking forward to new installations.
- Regarding pure R&D, the idea is to couple Edge AI and evolutional algorithm, such memetic to promote local intelligence over a global geographic, time and machine distributed systems.
- We are therefore welcoming other H2020 projects.

IN2DREAMS

User Applications

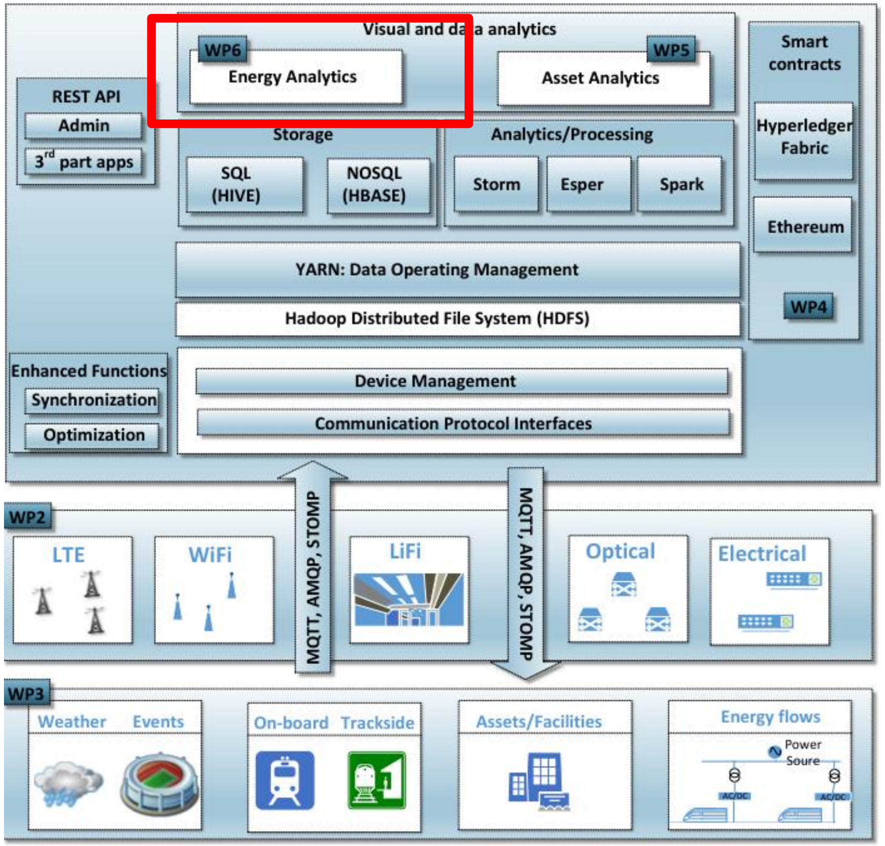
SIMONA SOLDI (EVOLUTION ENERGIE)

IN2DREAMS Final Conference, Milan, 02.10.2019

IN2DREAMS

User applications – WP6

General goal: to assist infrastructure managers and railway operators to select optimal strategies and resources in order to support in a cost-effective and energy-efficient manner, a variety of railway applications



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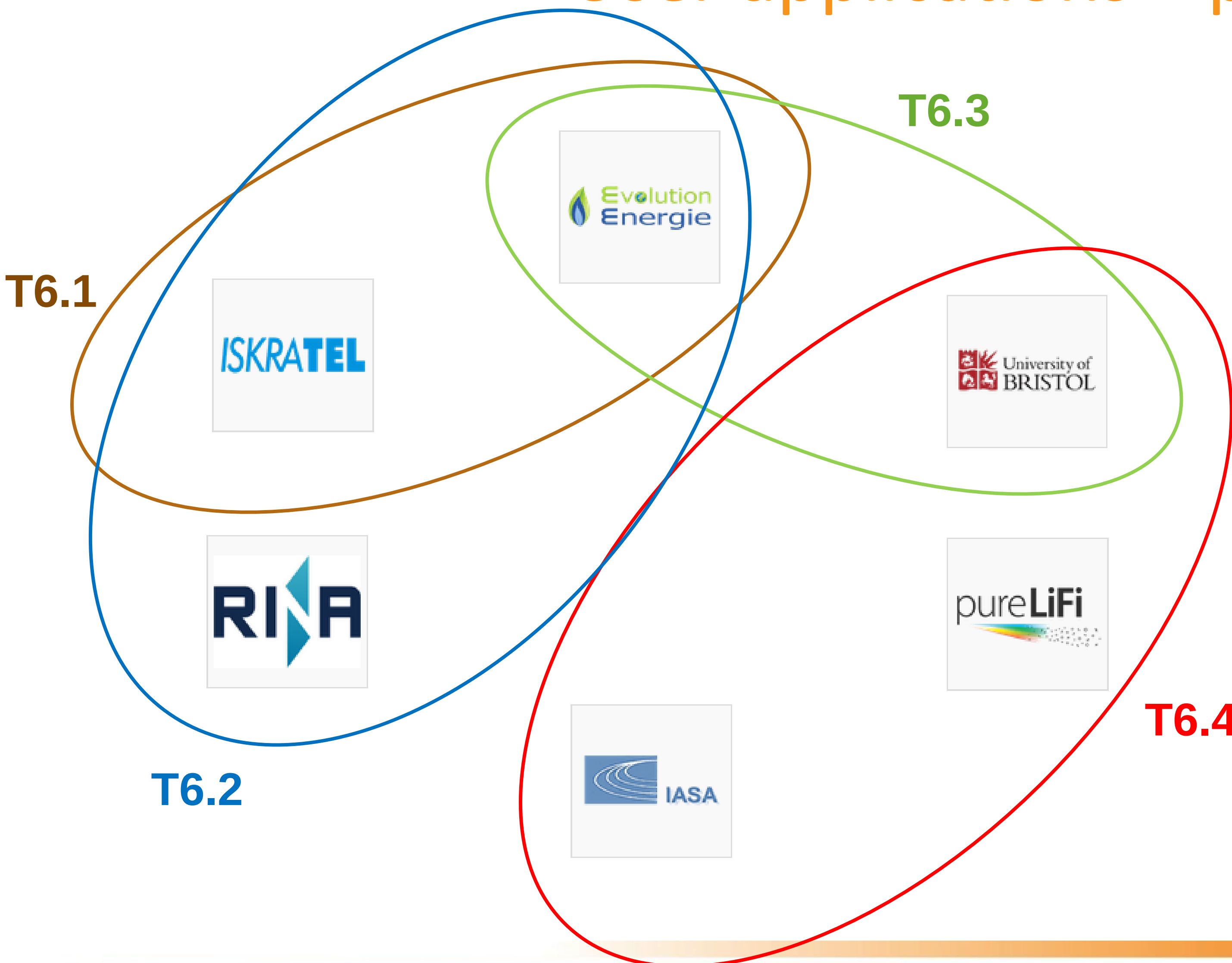
User applications – partners



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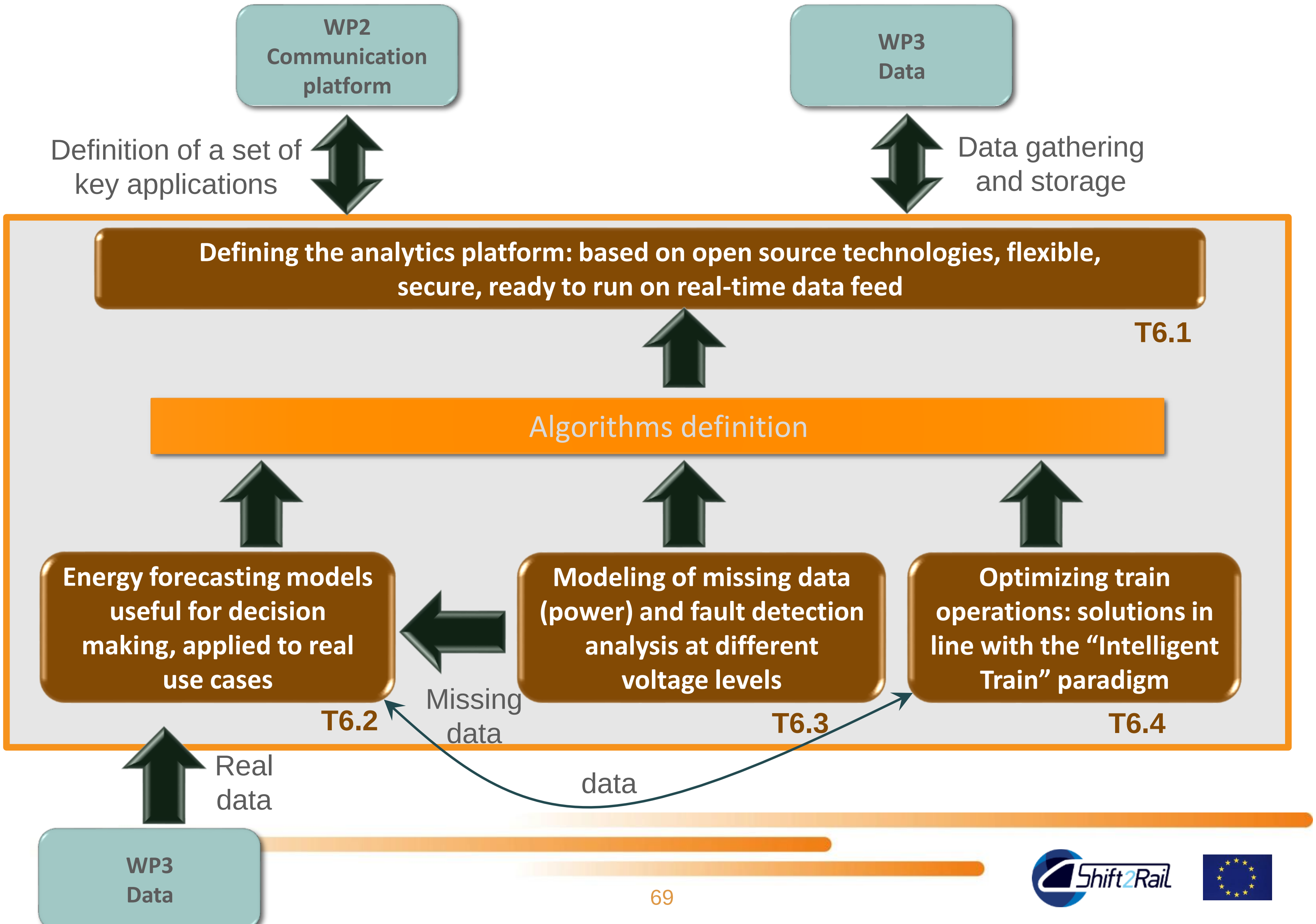
How we achieved these goals



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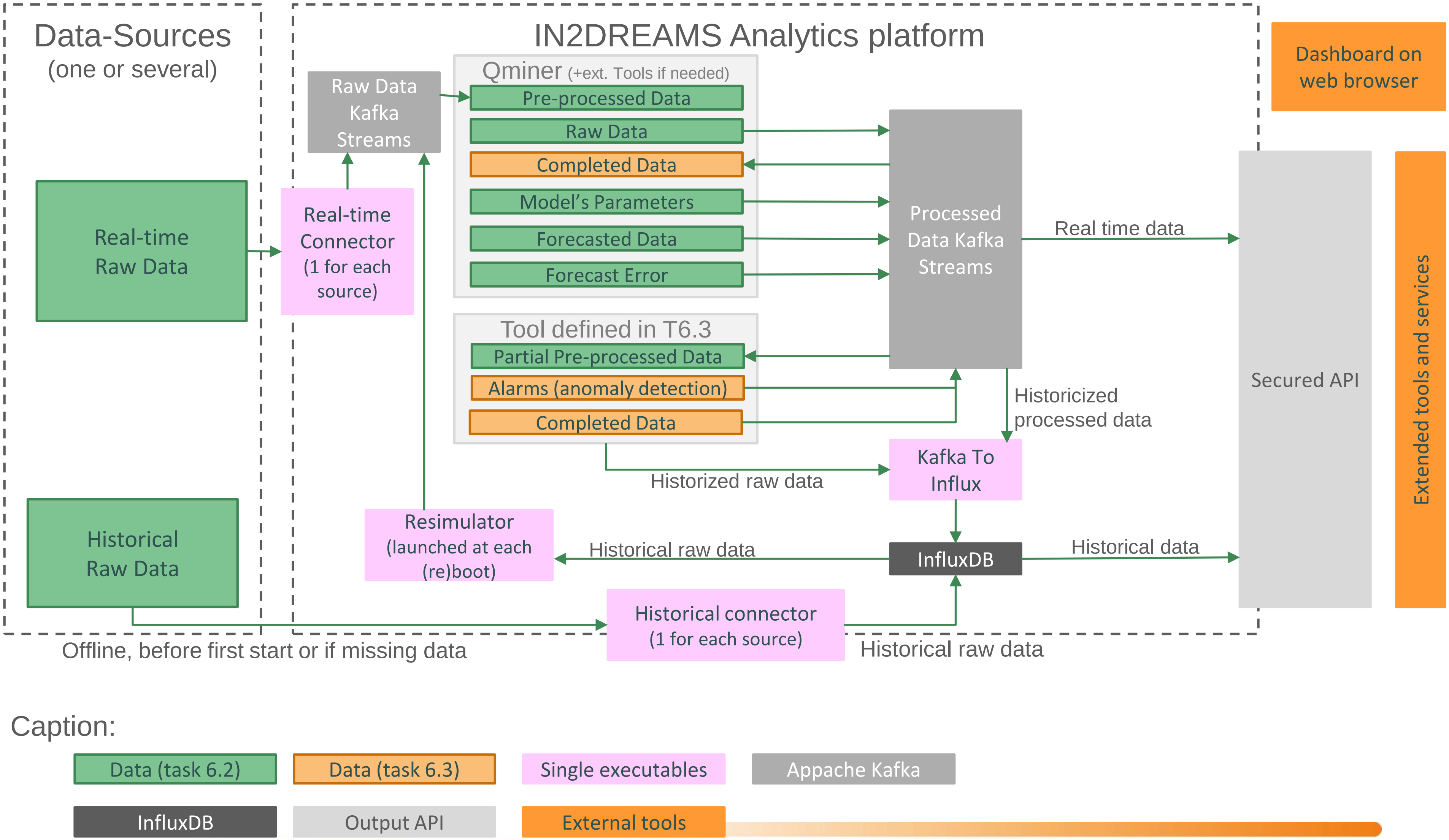
T6.1 - Analytics platform



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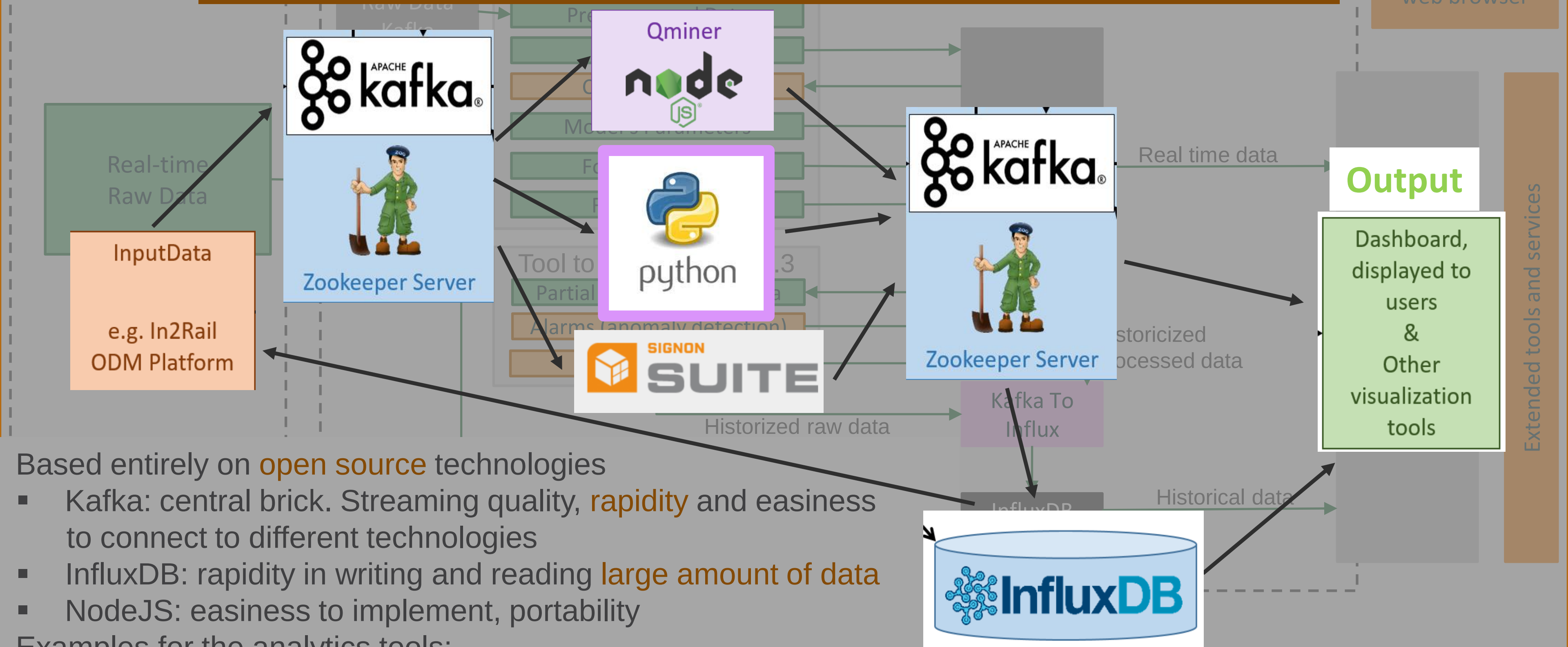
T6.1 - Analytics platform

Goal: Defining the analytics platform to be used in the rest of the WP
Partners: Evolution Energie, ISKRATEL



Based entirely on open source technologies

- Kafka: central brick. Streaming quality, rapidity and easiness to connect to different technologies
- InfluxDB: rapidity in writing and reading large amount of data
- NodeJS: easiness to implement, portability

Examples for the analytics tools:

- Qminer: large scale, real-time data processing, fast prototyping
- Python: machine learning libraries
- Signon: complete simulation tool for railway systems, Alstom expertise

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IN2DREAMS

T6.2 - Forecast modelling

Goal: Providing energy portfolio analytics useful for decision making
Partners: ISKRATEL, Evolution Energie, RINA-C

- Development of energy forecasting models based on two use cases:
  1. FULL node: on-ground unit, advanced computation with complex algorithms, distributed and parallel computing. Forecast time horizons from 1h to 24h
  2. LIGHT node: on-board unit, very fast response from computationally less demanding instance. Very short-time forecasts from 1s to 30s

- Applied to a real case: data from tram in Reims (France), instrumented by Alstom, data sent in real-time to Bristol University (IN2RAIL project)
  1. 1 power substation, 3 months of data, 1 second sampling
  2. 2 trains with data from 2015 to 2018, 1 second sampling

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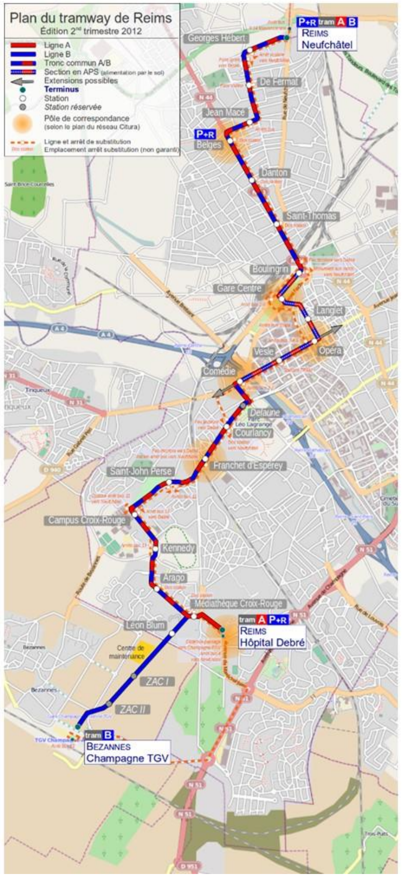
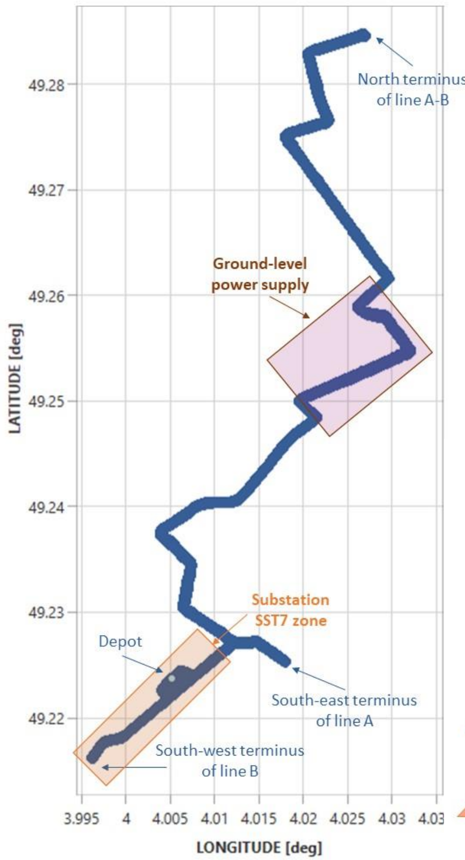
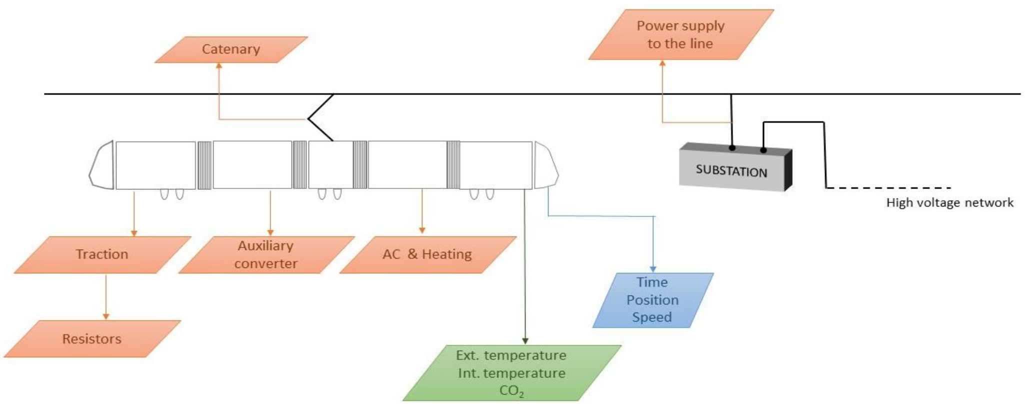
T6.2 - Reims tram data





- On-board data: traction and auxiliary power, ambient measurements, train dynamics
- Trackside data: power to three different feeders (depot, southbound, northbound)



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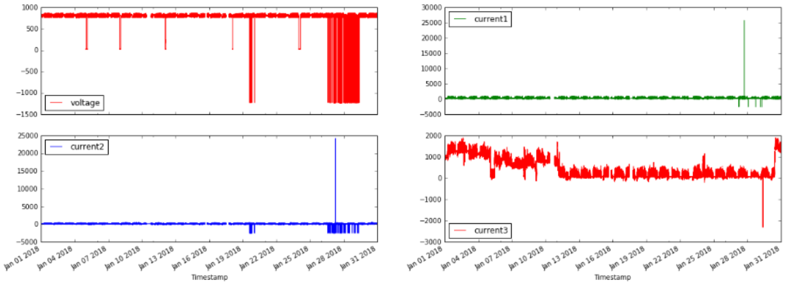
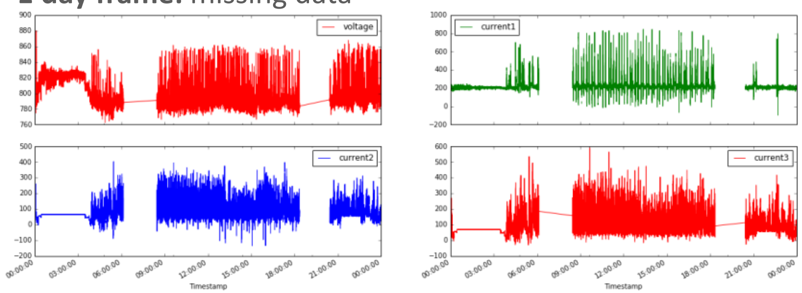
T6.2 - Data pre-processing

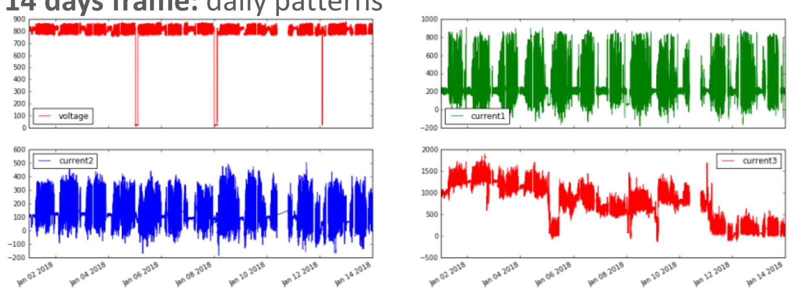
1 month frame: outliers



1 day frame: missing data



14 days frame: daily patterns



- Data cleaning (outliers, offsets, conversions, etc.)
- Data quality flagging
- Data interpretation
- Data fusion (weather data and static)

Flagging of train data at depot

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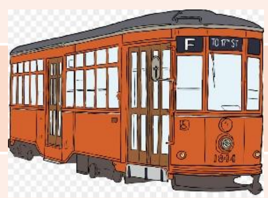
IN2DREAMS

T6.2 - Forecast modelling results

- Feature engineering and selection
- Model testing, selection and evaluation
- Integration into the analytic platform
- Assessment of forecast models for project use cases

	Train – Light node	Substation – Full node
Tools	Qminer (Node.js), RabbitMQ	Qminer, Kafka Broker, Python (scikit-learn)
Model	Ridge Regression	Random Forest
Features	position short-term E	date/time short-term E
Horizons	1s to 30s ahead	1h to 24h ahead
Application	short-term (10s) regulation to avoid consumption peaks on acceleration (getting power from on-board batteries and switching off systems, e.g., AC)	1) choosing the best mix of energy sources (storage, renewable, external grid) to optimize objectives; 2) predictive maintenance of substations knowing in advance power fluctuations



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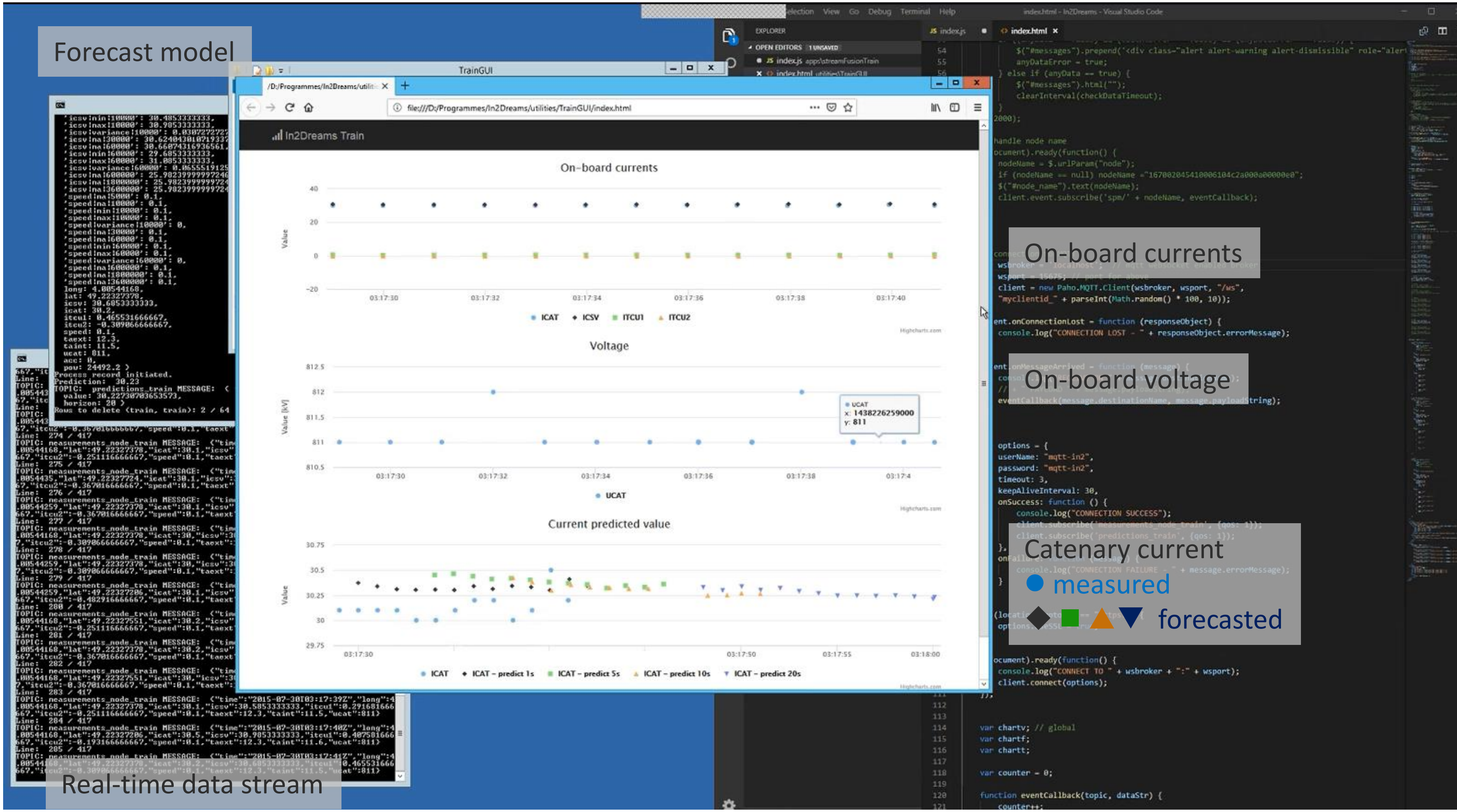
T6.2 - Streaming model results



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T6.2 - Forecast modelling results

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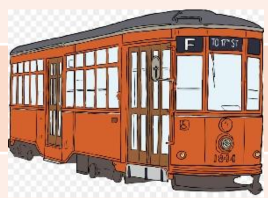

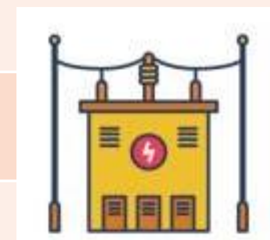

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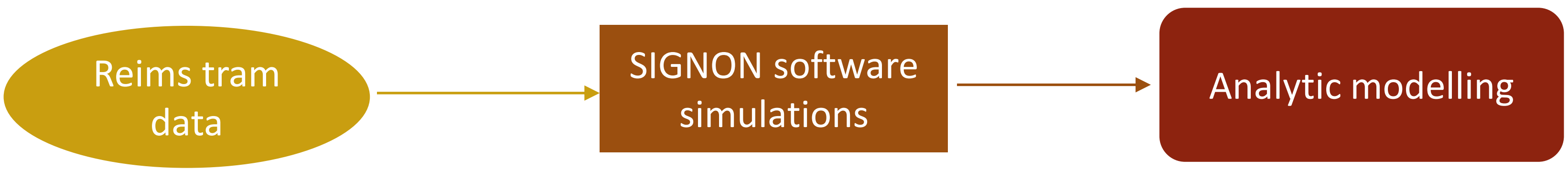
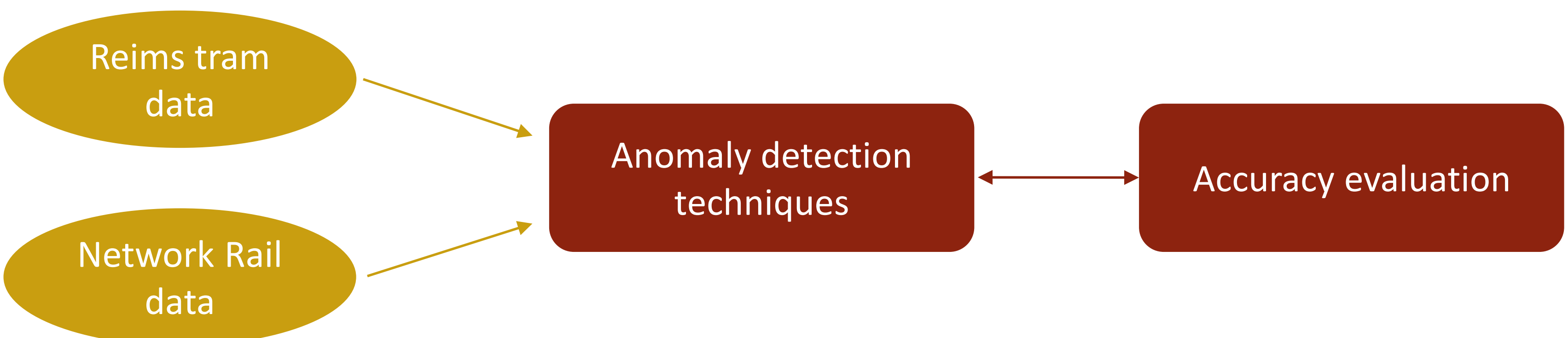
T6.3 - Power system modelling and fault detection

Goal: Enriching the analytics with system simulations and fault detection mechanisms
Partners: Evolution Energie, Bristol University

1. Modeling of missing data (voltage, current) through power system modelling



2. Fault detection analysis as function of voltage level



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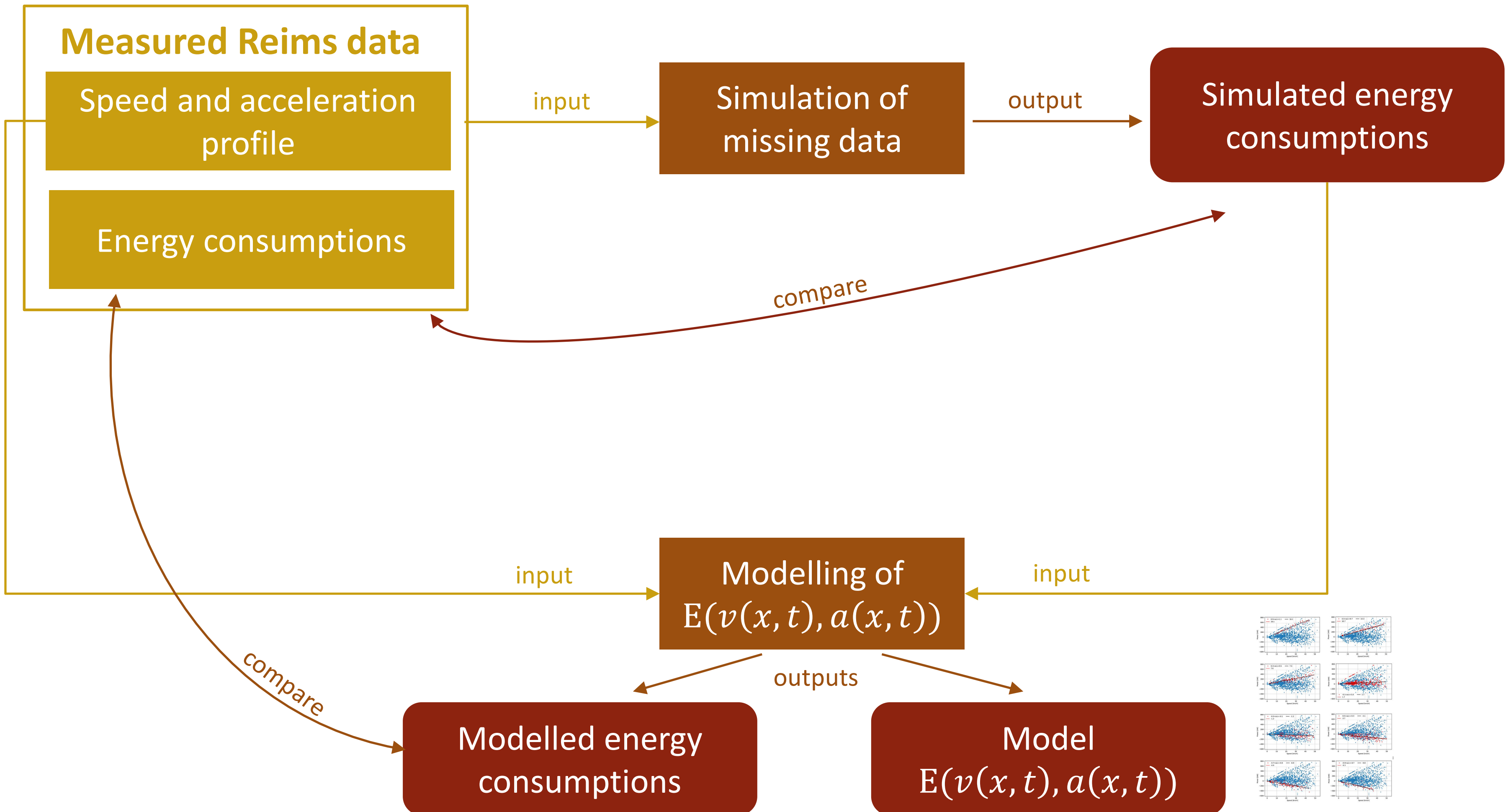
T6.3 - Modelling of missing data

Goal: estimating consumptions from the velocity and acceleration profiles $v(x,t), a(x,t) \rightarrow E(x,t)$



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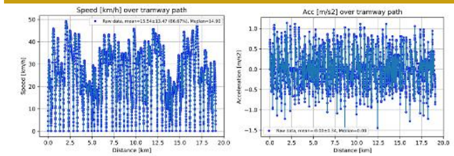
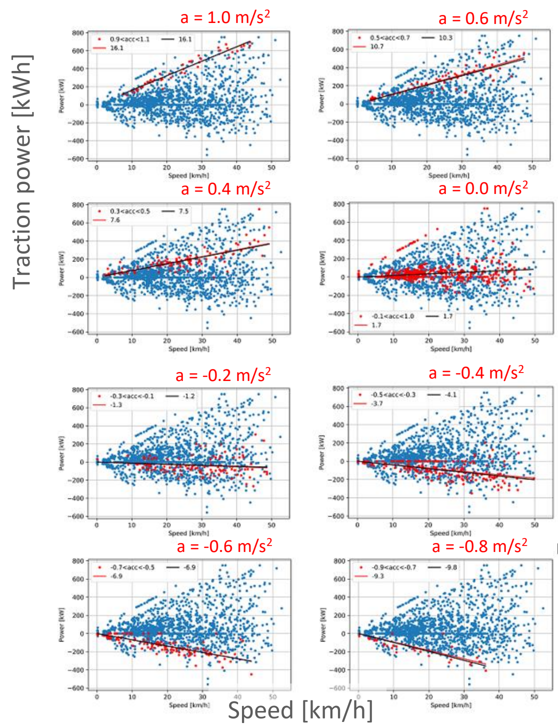
T6.3 - Modelling of missing data

Measured Reims data

Speed and acceleration profile



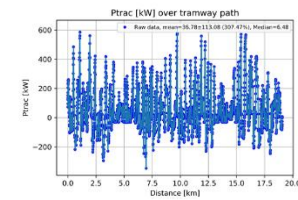
input



$$P_{TRAC} = Speed * (1.7 + 14.4 * Acc)$$

output

Modelled energy consumptions



input

Prediction Models

output

Predicted energy consumptions

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T6.3 - Fault detection analysis

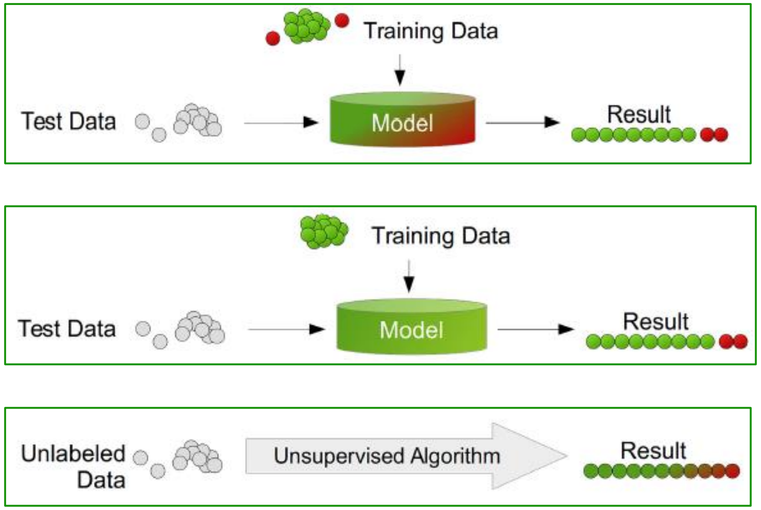
Goal: fault detection analysis of power consumption as a function of voltage level

- Finding unusual patterns not conform to the expected behavior. But what is unusual?
- Two use cases at different levels of voltage operation:
  1. Reims tram network (on-board data): Gradient Boosting
  2. Network Rail (Autotransformer substation on the Liverpool-Manchester line): Compressive Sensing + Neural Networks

Supervised methods:
fully labelled training set

Semi-supervised methods:
only normal cases in the training set

Unsupervised methods:
unlabelled training set



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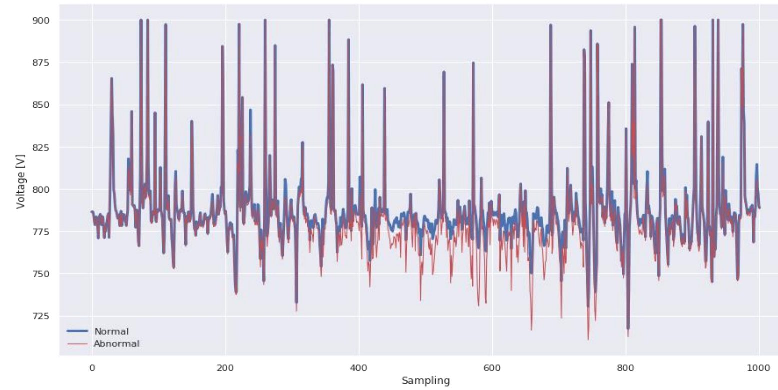
IN2DREAMS

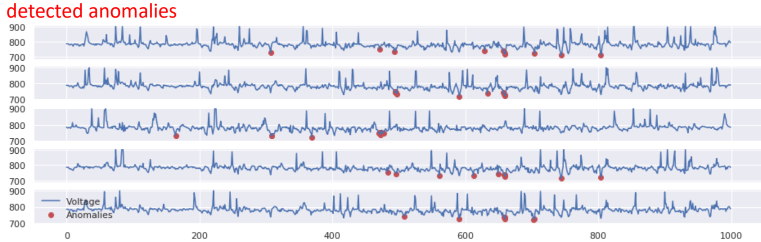
T6.3 - Fault detection analysis: low voltage

- Reims tram: 750 V, 1Hz data sampling, on-board voltage
- Goal: detect the location of substation anomaly from on-board data (E. Stavropoulos et al., TRA 2020) in simulations performed by SIGNON software

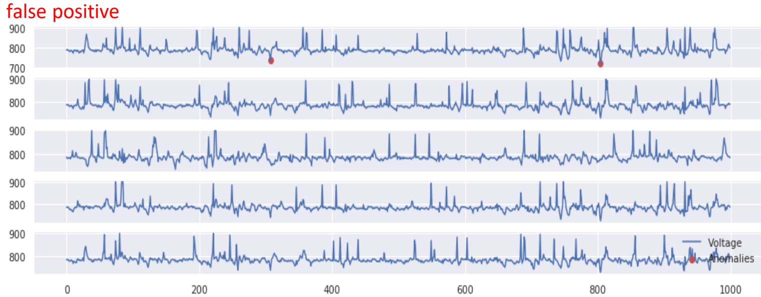


Moving Average Threshold: low complexity, no location info

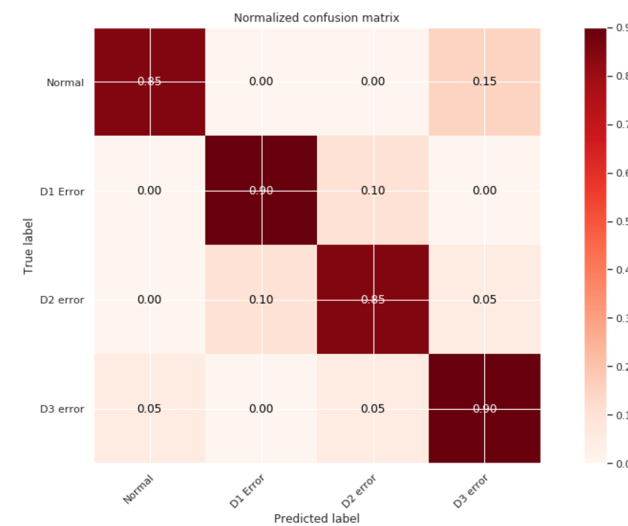
detected anomalies



false positive



Gradient Boosting and XGBoost: high complexity, exact location



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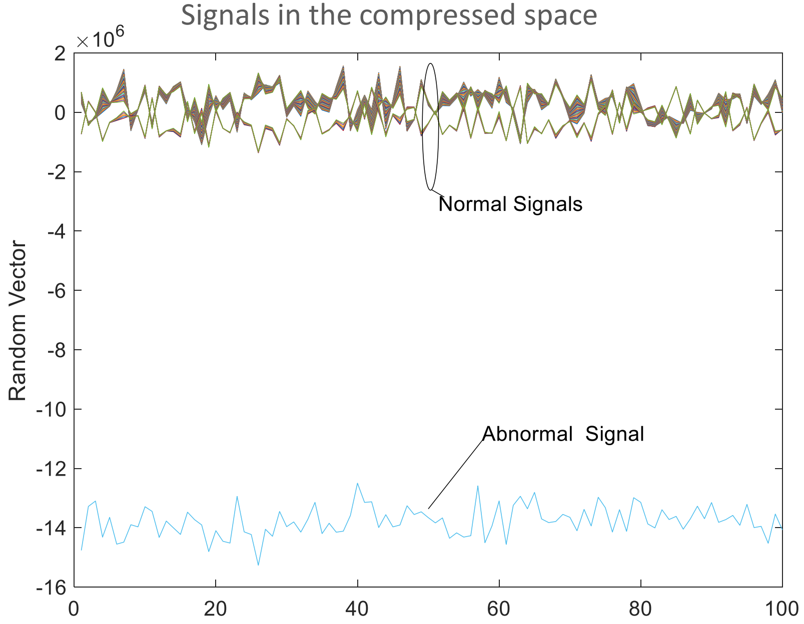
T6.3 - Fault detection analysis: high voltage

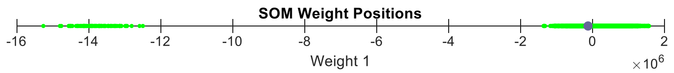
- Network Rail use case: 25 kV, 10 kHz data sampling, Overhead Contact System voltage
- New technique: Compressive Sensing + Neural Networks (Anastasopoulos et al. 2016, Anastasopoulos et al., TRA 2020)
- The recovered signal approximates the non-compressed abnormal signal with very high accuracy


Willow Park Auto Transformer Feeder Station

Signals in the compressed space



Output from Neural Network analysis



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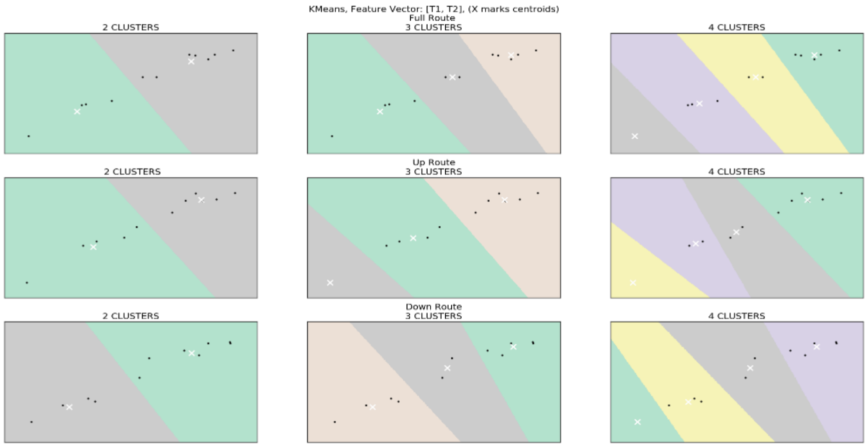
IN2DREAMS

T6.4 - Operations optimization

Goal: Development of solutions in line with the “Intelligent Train” paradigm
Partners: Bristol University, IASA, pureLiFi

- ***Offline Optimization Model***
  - New technique based on Data Envelopment Analysis (DEA) (Achilleos et al., VEHITS 2019, Springer LNCS 2020, to appear)
  - History observation can be optimally combined to improve the operational efficiency of the system
  - Modeling framework based on Integer Linear Programming (ILP)
- Example: Estimation of the optimal driving profiles
  - ***Step 1***: Selection of the appropriate dataset using clustering

Route clustering based on CO2 (on-board+External temperature)



T6.4 - Operations optimization

- ***Step 2:*** *Identification of the Efficiency Metrics (Interstation traveling time, Total Energy consumption, Number of passengers transferred etc.)*

Timestamp	External Temp	Speed	Current HVAC C2	Voltage (catenary)	Current (Ventilation)	Voltage HVAC	Total Energy Pantograph
	°C	km/h	A	V	A	V	kWh
1442729913	10.8	43	15.6	892	38.7	449.32	37.0573402
1442729914	10.8	40.8	15.6	891	37.9	449.28	37.00736674
1442729915	10.7	38.9	15.6	869	38.2	449.55	36.95579201
1442729916	10.7	36.9	15.6	874	38.2	449.64	36.90263086
1442729917	10.8	35.1	15.6	855	39.5	449.73	36.85689206

- ***Step 3:*** *Evaluation of the efficiency score θ of each driving style through the solution of the following (dual) problem:*

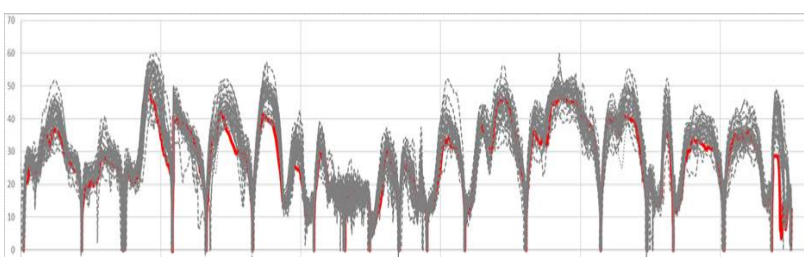
$$Max\ \theta$$

input $$\sum_{i \in S} \lambda_i x_{ij} \leq \theta x_{0j} \ , \forall j \in N$$

output $$\sum_{i \in S} \lambda_i y_{ij} \geq y_{0j} \ , \forall j \in M$$

Produce more output with less input

- ***Step 4:*** *Estimation of the efficiency scores and the best performing driving style*



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T6.4 - Implementation

- ***Implementation in GAMS: Input Example***

Input

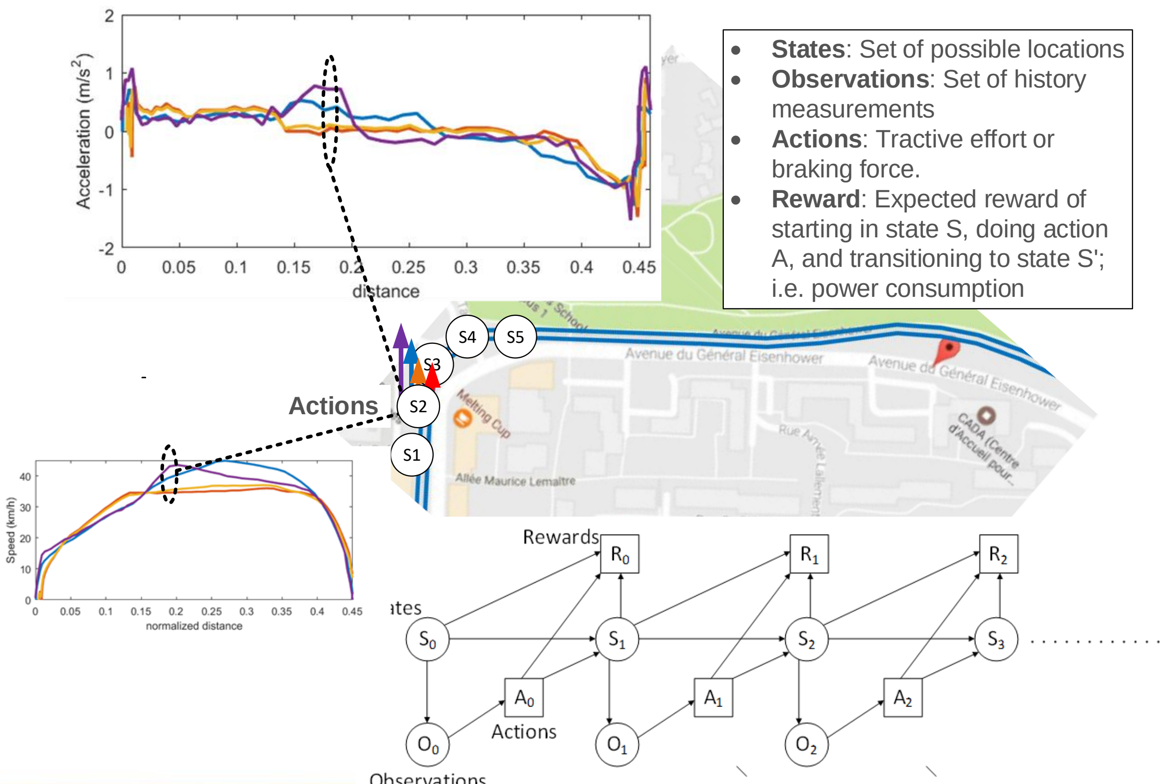
```
Table data(i,j)
              Acc            Power          Revtime      Speed          CO2
Route1        0.942232346    128704.6061    1755         17.41509681    42.22357631
Route2        0.919242597    129777.278     1755         17.49764806    38.60614465
Route3        0.999685864    131379.2679    1718         17.78226294    32.53169284
Route4        0.972339043    139132.7502    1693         18.15461629    34.02231405
Route5        1.046637832    149468.205     1733         17.65260092    35.52324106
Route6        0.963771429    140220.7884    1750         17.56293547    37.49115363
Route7        1.024353591    160885.694     1810         16.74152402    48.20745445
Route8        1.111648094    163884.4355    1705         17.94290739    42.38620164
Route9        0.866319       125764.1       1812         16.97582       35.4972
Route10       0.897807991    130571.2956    1802         17.21785912    28.54641154
Route11       1.050503067    145805.5571    1630         18.87853988    34.46166871
Route12       1.101036514    146366.4026    1698         18.01551826    37.33954653
Route13       1.088291714    155420.4908    1763         17.39755959    34.8927412
Route14       0.996927195    141505.0625    1869         15.57662062    38.71608491
Route15       0.926585101    137176.2977    1839         16.65852637    37.22825449
Route16       0.906586188    129699.0044    1782         17.1998091     50.14574958
Route17       1.100889571    142595.5615    1630         18.85820859    32.76369939
Route18       1.060148898    142383.0907    1679         18.43340083    32.78078618
Route19       1.007706587    117970.5156    1670         18.44902994    32.25292216
Route20       1.190570749    170094.5498    1682         18.19022592    39.27902497
```

Output

```
rnk1 .Route11 1.0000
rnk4 .Route4  1.0000
rnk4 .Route16 1.0000
rnk4 .Route17 1.0000
rnk6 .Route9  1.0000
rnk6 .Route19 1.0000
rnk7 .Route2  1.0000
rnk8 .Route8  0.9981
rnk9 .Route20 0.9909
rnk10.Route10 0.9899
rnk11.Route1  0.9831
rnk12.Route6  0.9693
rnk13.Route18 0.9618
rnk14.Route3  0.9591
rnk15.Route12 0.9576
rnk16.Route7  0.9530
rnk17.Route15 0.9342
rnk18.Route5  0.9230
rnk19.Route13 0.8812
rnk20.Route14 0.8290
```

T6.4 - Implementation

- ***Real time optimization***
  - For every location we can select the optimal actions (acceleration) using history and current observations
  - Objective: Minimize expected cost i.e. power consumption



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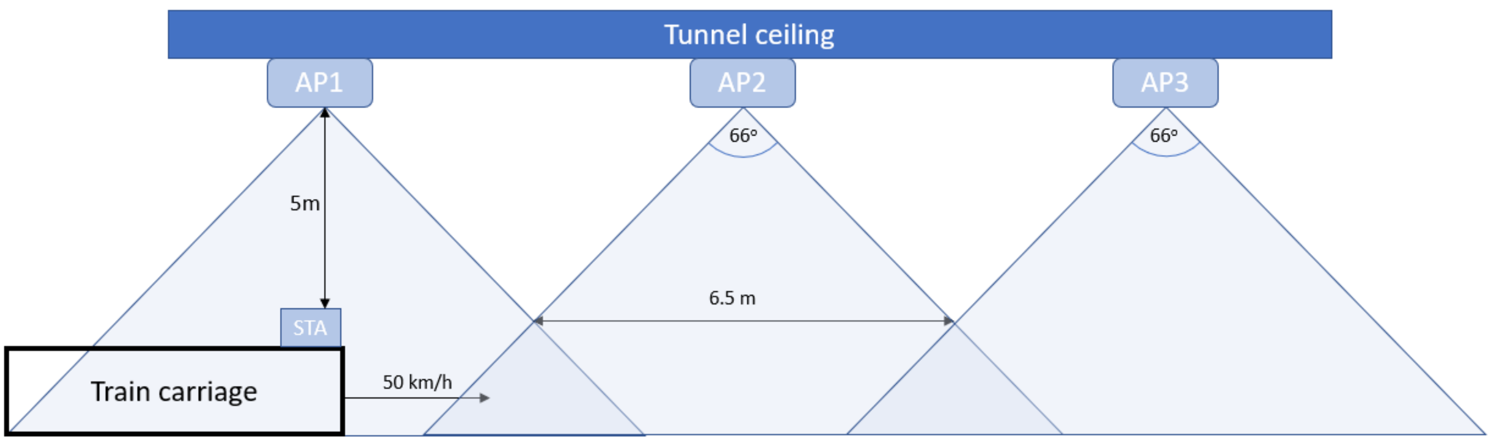
T6.4 - In-tunnel, LiFi based localisation

- Principle of operation:
  - LiFi Access point mounted on ceiling
  - LiFi Station mounted on train
  - LiFi Access points periodically transmits beacons, containing unique identifier (MAC address)
  - LiFi Station detects beacon, based on MAC address location can be determined



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T6.4 - Localisation system prototype

- System architecture
  - Based on pureLiFi's LiFi-XC system
  - 3 Access points, 1 Station
  - Station reporting detected MAC address to MQTT subscriber
- Test results
  - Functional test: Successful
  - Maximum velocity: 400km/h

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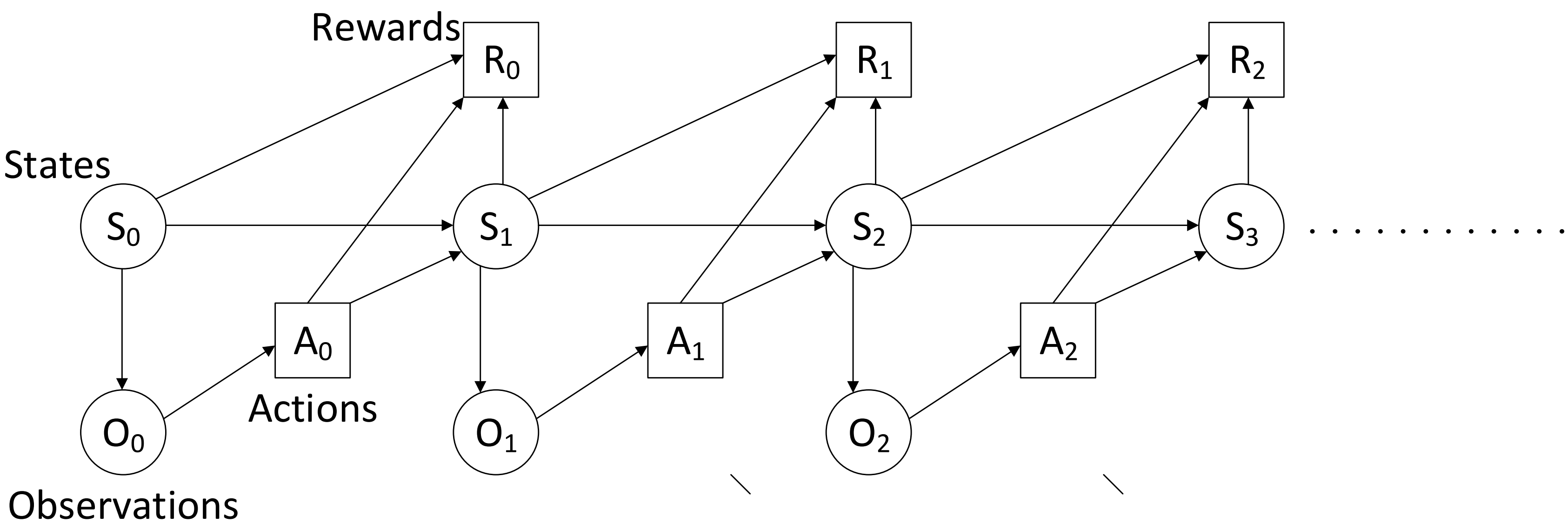
T6.4 - Implementation

- Mathematical framework based on Markov Decision Process
- Basic Elements: States (locations), Observations (History), Actions (Acceleration, breaking), Rewards (efficiency score)



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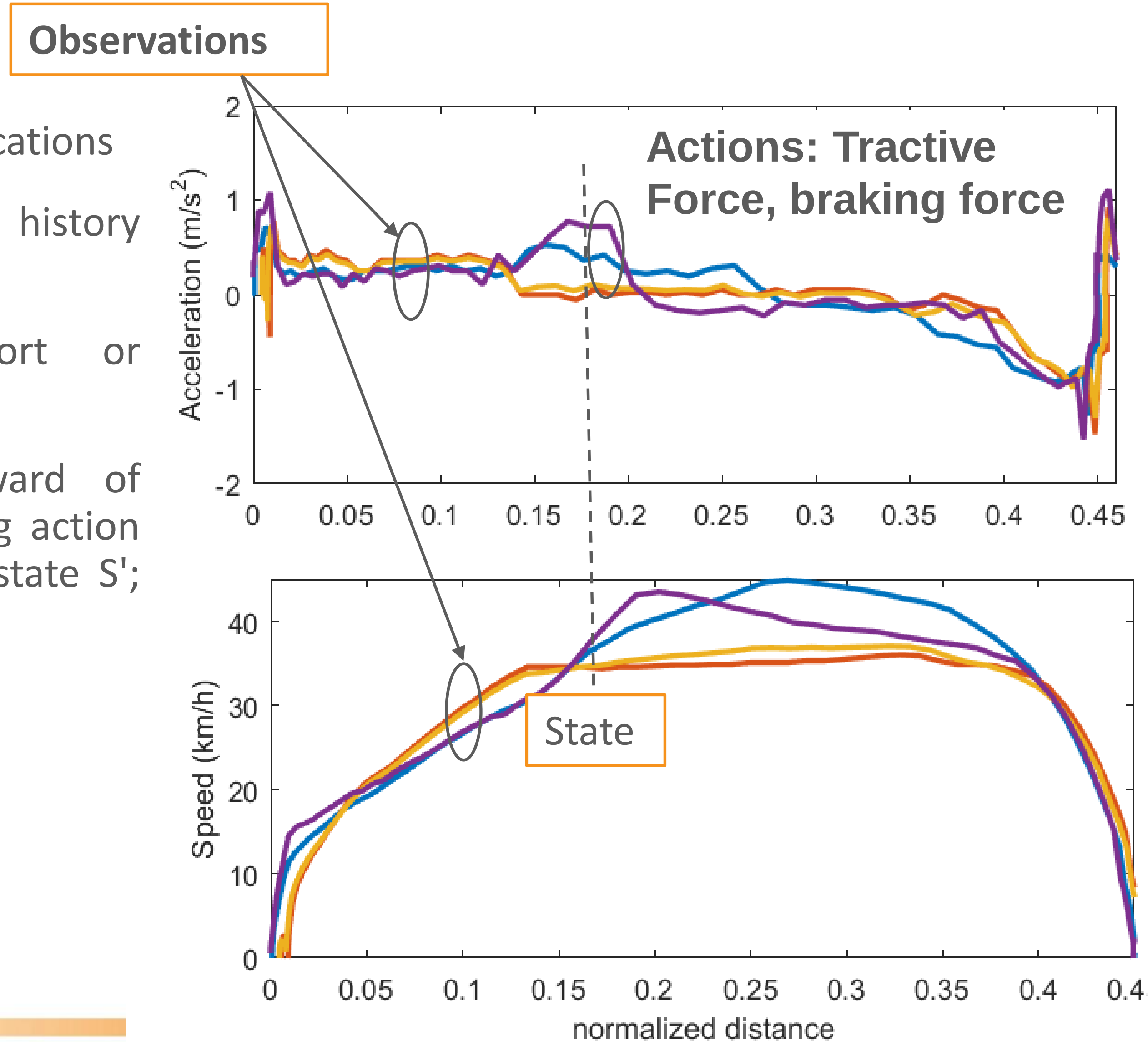
T6.4 - Implementation

States: Set of possible locations

Observations: Set of history measurements

Actions: Tractive effort or braking force.

Reward: Expected reward of starting in state S, doing action A, and transitioning to state S'; i.e. power consumption



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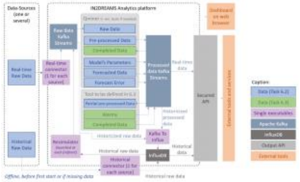
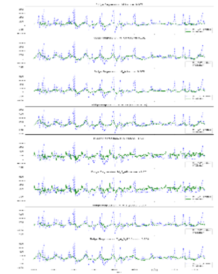
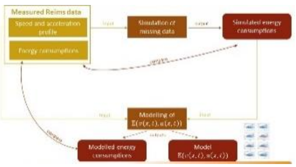
Summary and conclusions



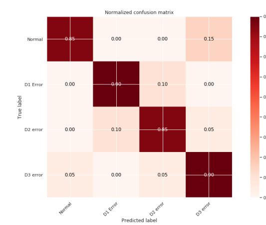
- Analytics platform: based on open source technologies, flexible, secure, ready to run on real-time data feed



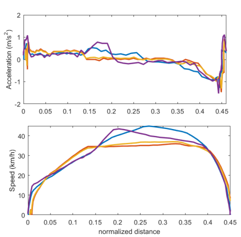
- Energy forecasting models for both on-board and track-side data



- Power system modelling to enrich existing but limited datasets



- Implementation of fault detection techniques for anomaly detections for two uses cases



- Development of solutions in line with the "Intelligent Train" paradigm for operations optimization (optimal driving profiles)

Simona Soldi – Evolution Energie – simona.soldi@evolutionenergie.com

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IN2DREAMS

Smart contracts for Railway Data Transactions

NADIA FABRIZIO (CEFRIEL)
DIMITAR ANASTASOVSKI (CEFRIEL)

IN2DREAMS Final Conference, Milan, 02.10.2019

Background- why DLT & Smart Contracts?

- Technology is **maturing**
- And is applicable beyond financial use cases
- To tackle the challenge of **«digital trasformation» in complex ecosystems**

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Scope

- Support the experimentation (TRL3) of novel data-driven methodologies in railway context

- Related to Technical Demonstrator 3.6- Dynamic Railway Information Management System (DRIMS).

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IN2DREAMS

Impacts and Actions

IMPACT	ACTIONS
Capacity improvement by more effective asset maintenance management	• Apply Data-driven methodologies • Develop an holistic approach to asset management and decision support including diagnostics and prognostics
Improved Reliability: by new “intelligent asset management”	• reduce unexpected maintenance interventions • increase reliability and availability
Significant LCC savings	• move from reactive and preventive maintenance to prescriptive maintenance based - • -nowcast and forecasting of asset condition and diagnosis
Improved safety	• Reduce of the number and magnitude of incidents will be reduced

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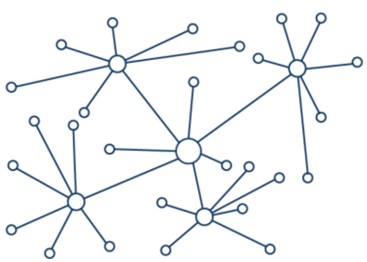
Outputs

Data and transactions security and safeguarding data ownership rights, in the contract mechanisms

WP4 Scenarios
- Asset Maintenance



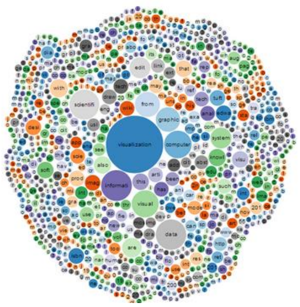
Cefriel
POLITECNICO DI MILANO

Evolution Energie

WP5 Scenarios
- Restoration Time
- Train Delay Prediction

UNIVERSITÀ DEGLI STUDI DI GENOVA

WP5 Scenario
- Visualization in Control Center



University of Konstanz

Shift2Rail

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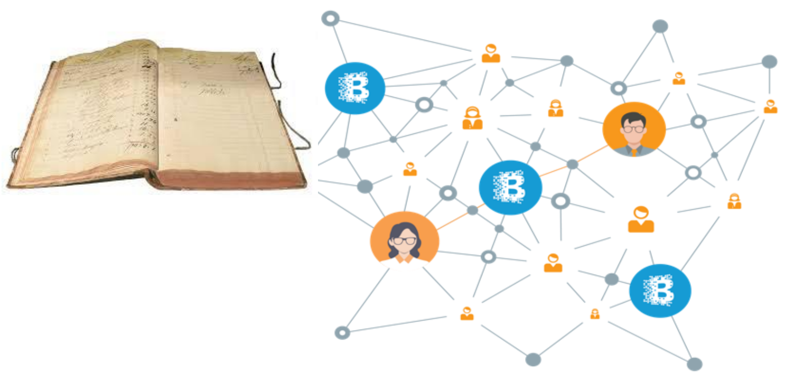
Background: why SMART CONTRACTS?

- Bitcoin and Cryptocurrencies are just applications powered by Blockchain technology
- More, **the applications** are **not limited to just FINANCE**

Emerging as a groundbreaking approach

Blockchain

Blockchain = chronologically timestamped ledger of transactions maintained by
a collaborative distributed "consensus" mechanism and operatin in a distributed network of nodes that keeps tracks of transactions



LEDGER

- The **ledger** is an append only database where information are stored in a **chronological order** with a **timestamping** in an **immutable** way
- Every subsequent block is appended to the previous with an hash pointer

+

CONSENSUS

- The **consensus** is the key mechanism that replaces the third party in the exchange of an asset or value, preventing double spends
- **It is based on majority of all nodes (public) or selected nodes (private)**

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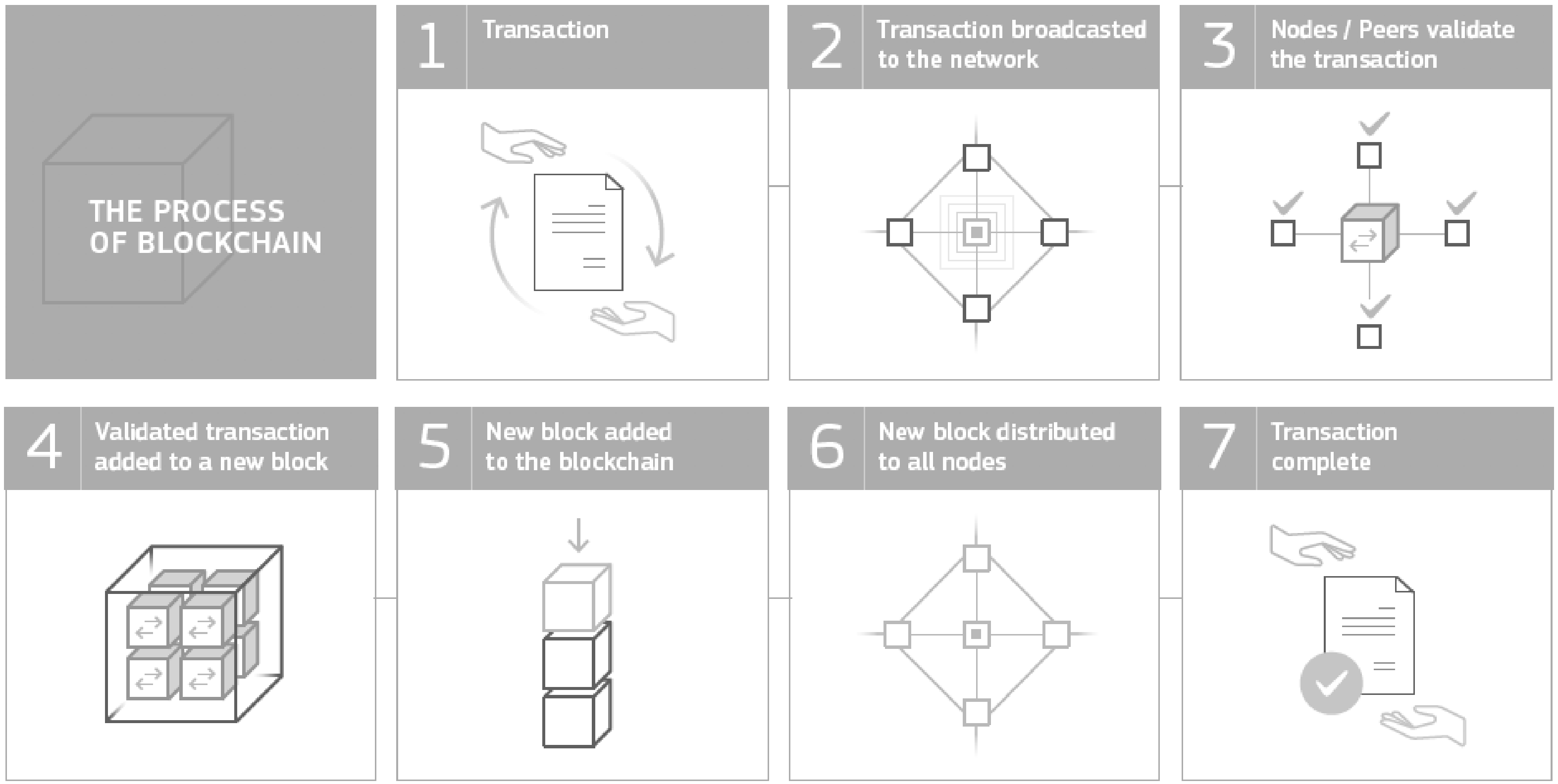
IN2DREAMS

Background: key concepts



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SC Are Not “Contracts” But Codes

- **SC=It** is a piece of software that executes its terms automatically and encodes rules agreed upon by all parties:

- Viewable by all parties
- Decentralized
- Can transfer value
- Can be triggered by events
- Every one in the network can verify
- Has its own address
- It is the owner of the digital asset

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Potential benefits

- Greater transparency
- Enhanced security
- Improved traceability
- Increased efficiency and speed
- Reduced Costs
- Enabling effective monitoring and auditing by participants, supervisors, and regulators

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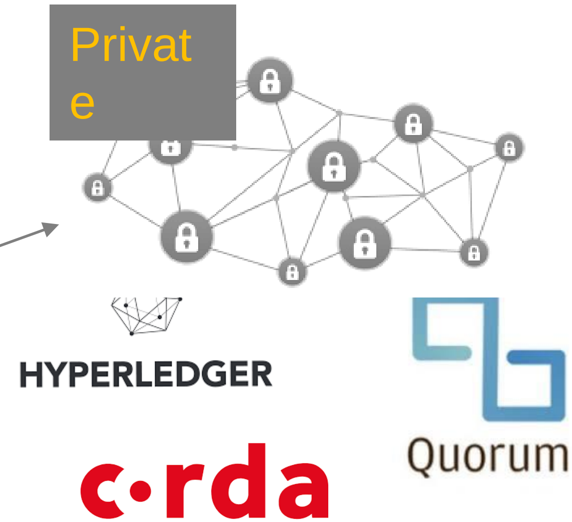
Approaches



- All nodes are **unknown**
- Everybody is free to become a node
- The consensus rely on: incentives (economic rules) + probabilistic approach (PoW, PoS,..)

- All nodes are **known**
- Perrmission is required to become node
- The consensus does not need explict incentive and reward

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IN2DREAMS

DLT overview of technologies

TECHNOLOGY DIVERSITY

DLT

The chronological register of transaction data

NON GOVERNED
Everybody is able to access DLT

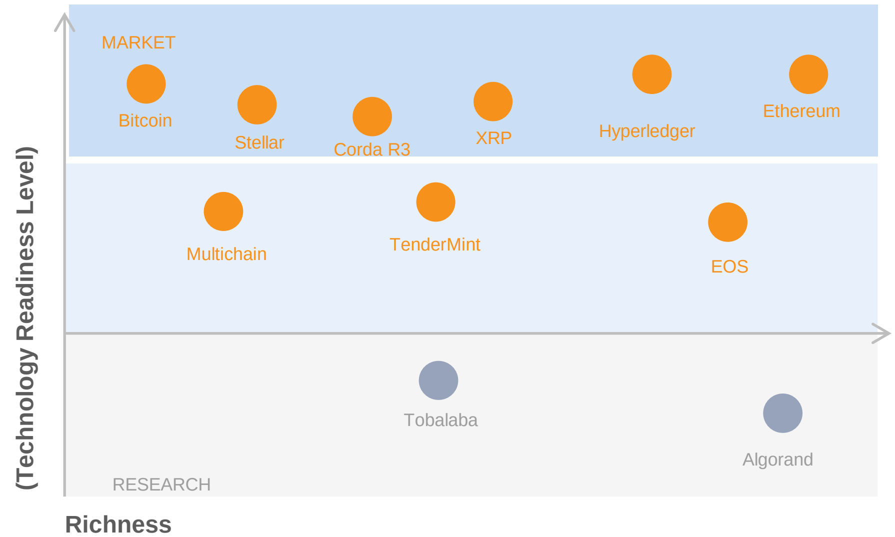
- **BITCOIN** — *The original protocol of the Bitcoin cryptocurrency*
- **ETHEREUM** — *The original "smart contracts" platforms*

GOVERNED
Nodes need a permission to access the network

- **CORDA R3** — *For financial use cases*
- **HYPLERLEDGER FABRIC** — *Every kind of context*

Classificazione-Progetto In2DREAMS CEFRIEL 2018

CEFRIEL'S MAPPING- APRIL 2019



IN2DREAMS DLT overview of assessment pillars

GOVERNANCE	SCALABILITY AND PERFORMANCE	TOKEN	INTEROPERABILITY	PRIVACY
Self organizing governance	Network is scaling with same performance	Posibility to Create token	Pragmatic interoperability	Data, ledger and participants are encrypted
Agreement by all participants	Acceptable scaling and performance	Token standardization	Semantic interoperability	Compliance regulation
Agreement by certain nodes	Medium number of nodes for scaling	Token exchange	Common data format	Data is encrypted
Centralized governance	Limited amount of nodes for normal performance	Only one Native token	Communication Protocol	Unauthorized access of participants
One governor for the whole network	System failure	There is no token	Stand- Alone	Append-only Data structure

BLOCKCHAIN ASSESSMENT © All Rights RESERVED CEFRIEL 2019

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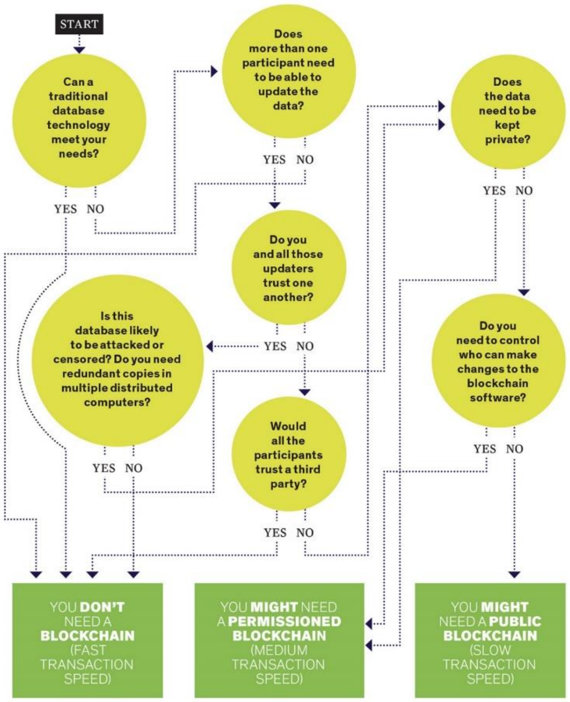
Emerged Scenarios



- **Asset Maintenance**-Manage the maintenance jobs workflow through the employment of smart contracts, automatically enforcing the rules and clauses (like SLA) of the maintenance contracts between the IM and the Contractor.
- **Public Procurement**-Employ the blockchain as a notarization platform for public procurements, taking advantage of its immutability property.
- **Data Monetisation**-Monetize owned data creating an ecosystem able to manage the access (and relative payments) to the data of the ecosystem's participants, employing smart contract to manage both the access rights and the payments.
- **Train Path Allocation**-Manage the international allocation of train path through the employment of smart contracts and blockchain to automatize the administrative workflow.

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SELECTED SCENARIO: Maintenance Scenario

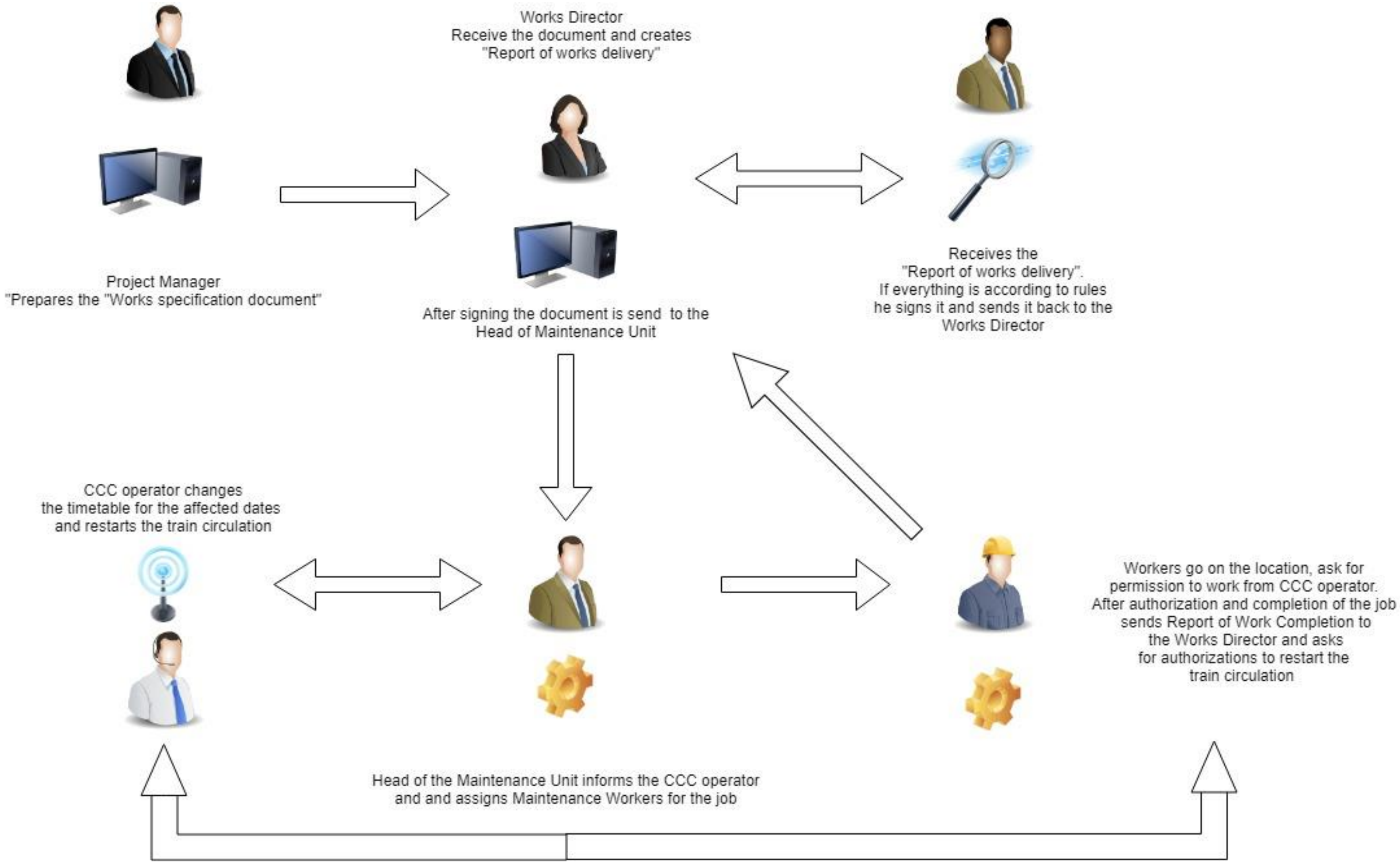
AS IS **Legacy systems**	**TO BE** ***With a «Blockchain back bone» might be ABLE to***
Do not guarantee trust across all actors belonging to the "ecosystem"	**Trust Enhance and security enhance** thanks to crash tolerance and secure timestamping.
Enforce business logic by participants through contracts	**Enforce Business logic** automation through smart contracts
Enforcing subjective rules making the business nontransparent	Enhanced transparency through ledger auditability
Limited process efficiency due to dated communication methods	Potential efficiency gains in terms of time and complexity

Methodology

- Evaluation of avalaible DLT framework and analysis of process worflows and bottlenecks
- Proof of concept

IN2DREAMS

AM Workflow



IN2DREAMS

App Layer: Functionalities

Table 5: Features and Roles: requirements

Features	PM	WorkDr	TechDr	CCC	HoM	Worker
Sign in and out, mgm of personal data	x	x	x	x	x	x
Creation of WSD	x					
Creation of RWD		x				
Change Status of WSD	x					
View all WSD in the system	x	x				
Sign RWD		x	x			
Able to view all RWD		x	x	x	x	
Assign workers			x			
Alert CCC			x			
Reschedule				x		
Create prediction document						x

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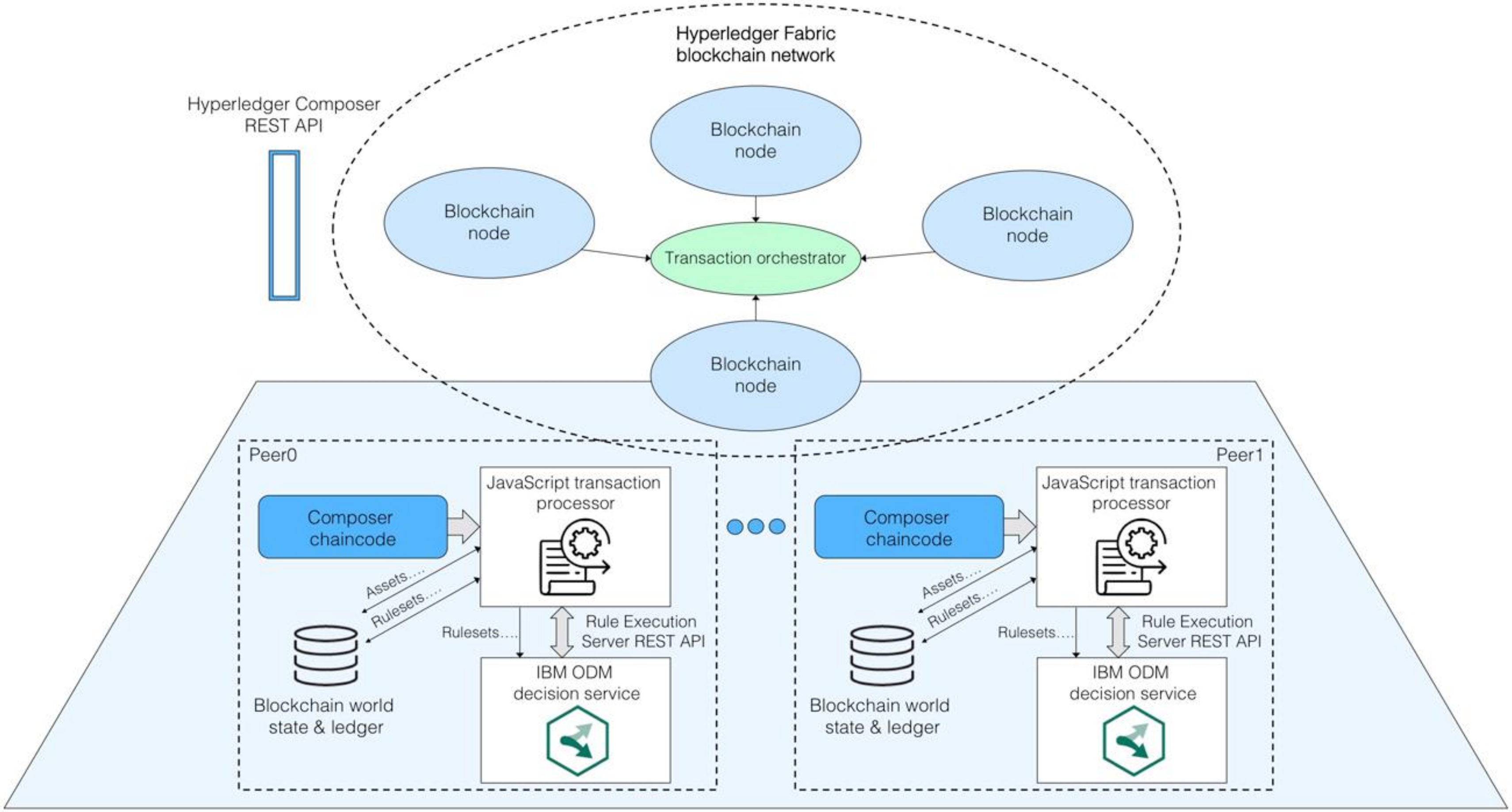
Chaincode detail view



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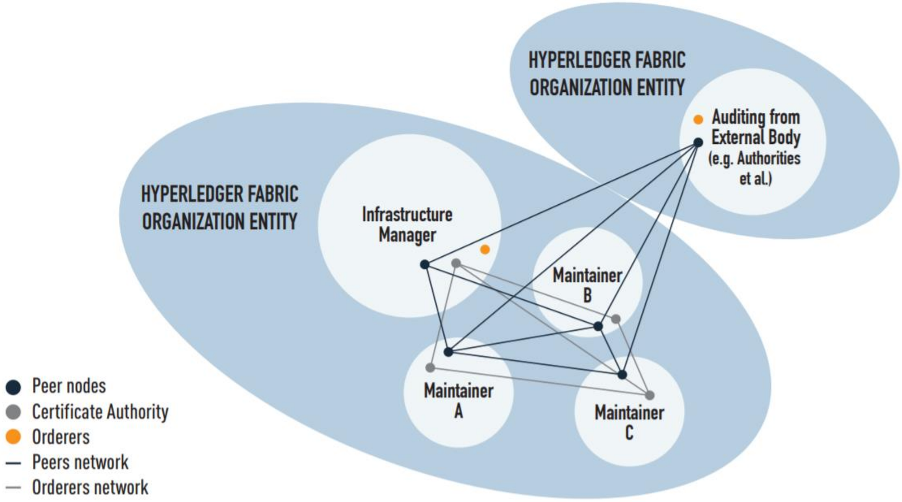
Network detail view

- **Each organization** has **its own peers** and a Certification Authority (CA).
- **Each CA** acts as a Membership Service Provider **(MSP)**
- The **network is globally administrated by the IM**
- Both the ledger and **the chaincodes** (smart contracts in Hyperledger Fabric) are replicated on every peer connected to the channel, providing redundancy of the data.
- The **ordering service** will be provided by a single orderer on a first testing phase, to be later developed to a crash tolerant Kafka cluster [1] on a later stage.



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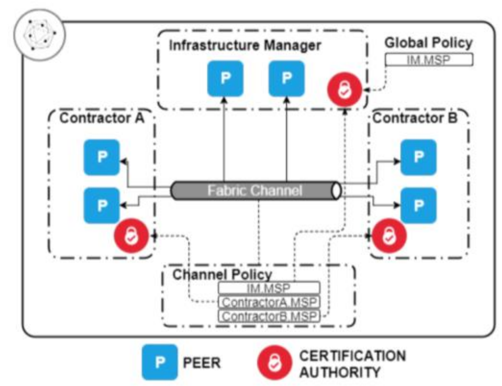
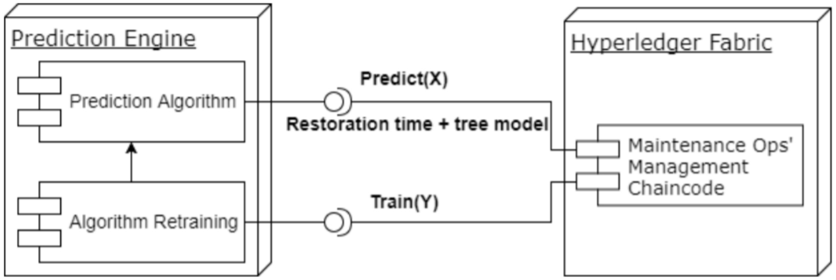
Blockchain + Prediction Engine combined

- **The prediction engine** needs to be able to automatically retrain (and therefore modify) the prediction algorithm, but chaincodes can only be updated manually.
- **The interconnection** between the two components will be developed through two REST APIs

Big Data and Distributed Ledger Technologies for Railway Maintenance





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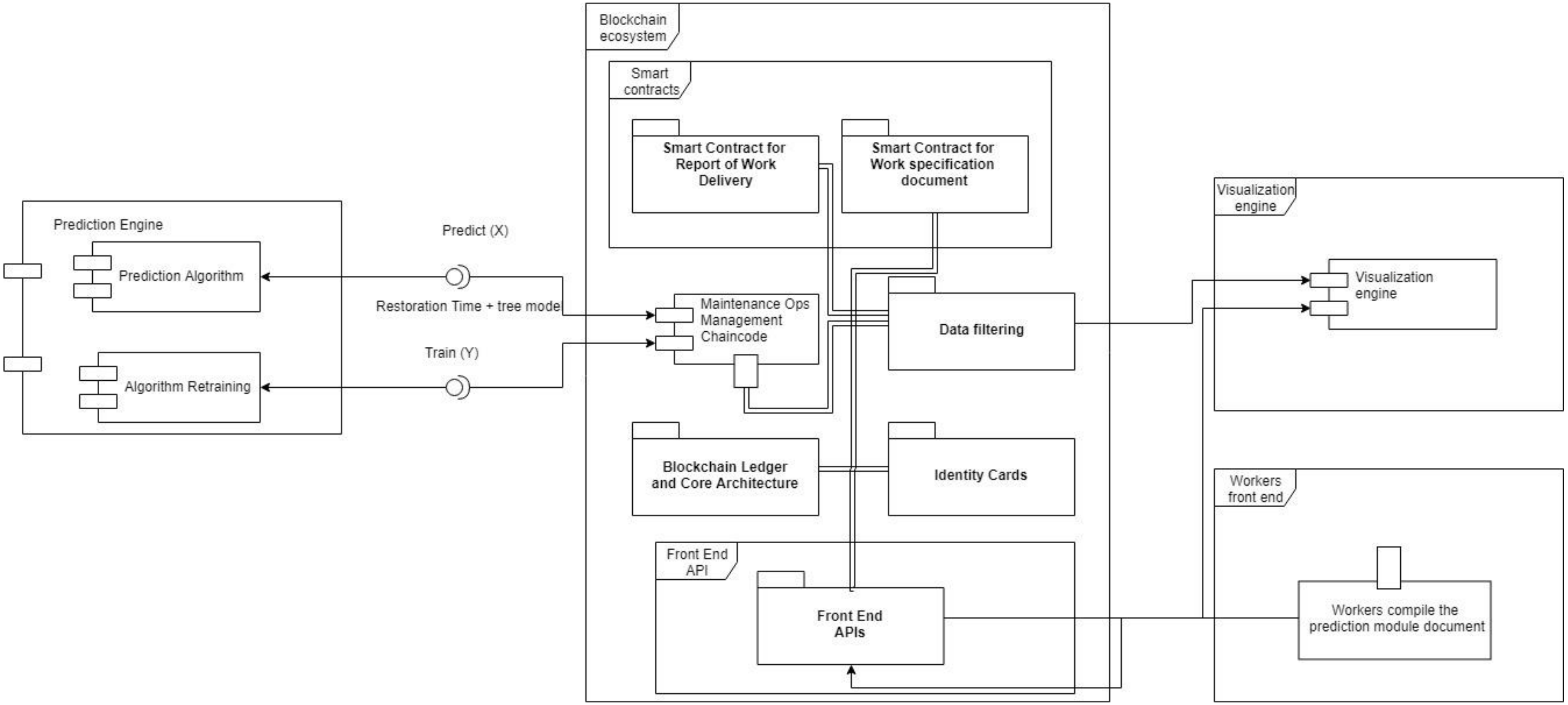
The integrated TD inside the Infrastructure MgM Scenario



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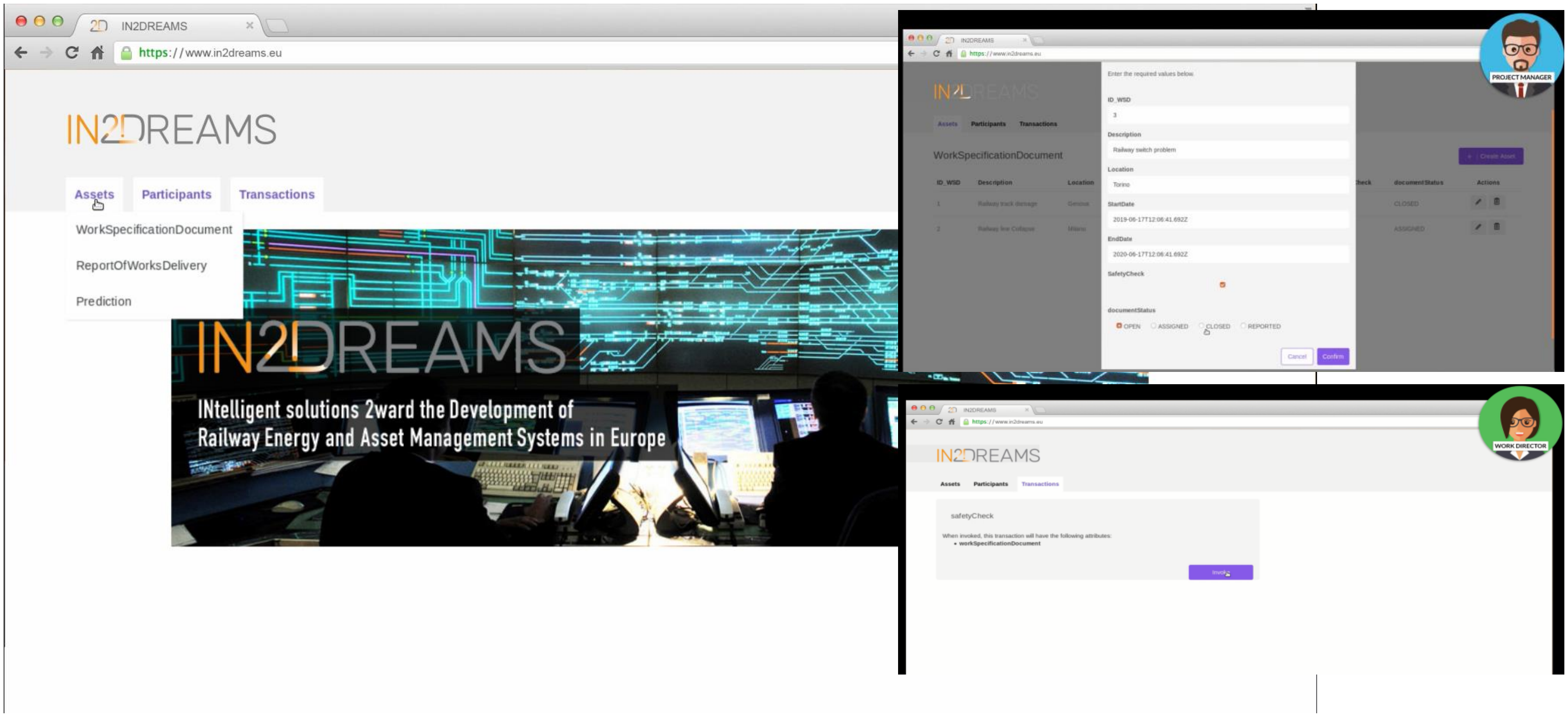
TD Overview



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TD Analysis

- Testing
  - Network-Benchmarking (Caliper)
  - Application –SC (stress test, unit test)
- Trial and Survey
  - User Exp
  - Business aspects/process

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Perfomance Testing –July 2019

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Table 6: Summary results from the two test rounds

Test	Name	Succ	Fail	Send Rate	Max Latency	Min Latency	Avg Latency	Throughput
1	in2dreams	25	0	8.3 tps	1.00 s	0.37 s	0.67 s	7.2 tps
2	in2dreams	50	0	13.2 tps	3.03 s	0.43 s	1.69 s	9.9 tps

Table 7: Round 0 results of performance testing with Caliper

Type	Name	Memory(max)	Memory(avg)	CPU(max)	CPU(avg)	Traffic In	Traffic Out	Disc Read	Disc Write
Process	node local-client.js(avg)	-	-	NaN%	NaN%	-	-	-	-
Docker	dev-peer0.org2..	99.7MB	99.7MB	0.01%	0.00%	0B	0B	0B	0B
Docker	dev-peer0.org1..	99.3MB	99.3MB	2.68%	0.89%	0B	0B	0B	0B
Docker	dev-peer0.org2..	82.0MB	74.3MB	30.19%	15.41%	378.8KB	355.8KB	0B	0B
Docker	dev-peer0.org1..	78.0MB	74.2MB	37.26%	27.44%	382.0KB	351.9KB	0B	0B
Docker	peer0.org2..	412.8MB	412.0MB	20.01%	13.73%	1.4MB	3.1MB	0B	456.0KB
Docker	peer0.org1..	374.6MB	345.0MB	29.96%	23.45%	1.4MB	3.1MB	0B	456.0KB
Docker	orderer.in2dreams.com	14.1MB	13.5MB	5.82%	3.34%	392.5KB	742.7KB	0B	432.0KB
Docker	ca.org1.in2dreams.com	9.9MB	9.9MB	0.00%	0.00%	0B	0B	0B	0B
Docker	couchdb.org1.example.com	104.8MB	103.6MB	51.18%	45.85%	384.9KB	590.1KB	0B	512.0KB
Docker	ca.org2.in2dreams.com	9.4MB	9.4MB	0.00%	0.00%	0B	0B	0B	0B
Docker	couchdb.org2.in2dreams.com	105.9MB	104.6MB	42.28%	30.55%	409.8KB	625.8KB	0B	524.0KB

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Perfomance Testing –July 2019

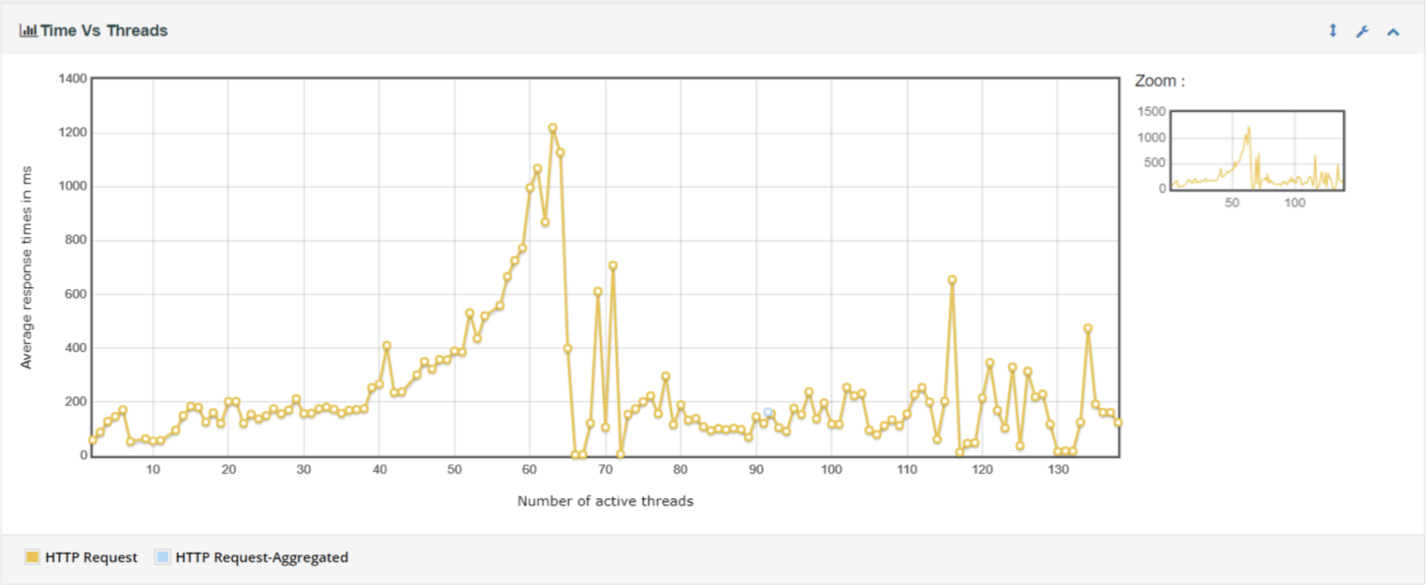

Figure 16: Average response Time of HTTP requests over Number of active threads

Survey Results (after trial on field)

it does not allow the revoking of signature, and the data are checked during the process but not at the input phase.

Needs for developing a more friendly and friendly user interface;

Need for including in the process the tracking and registering of physical assets.

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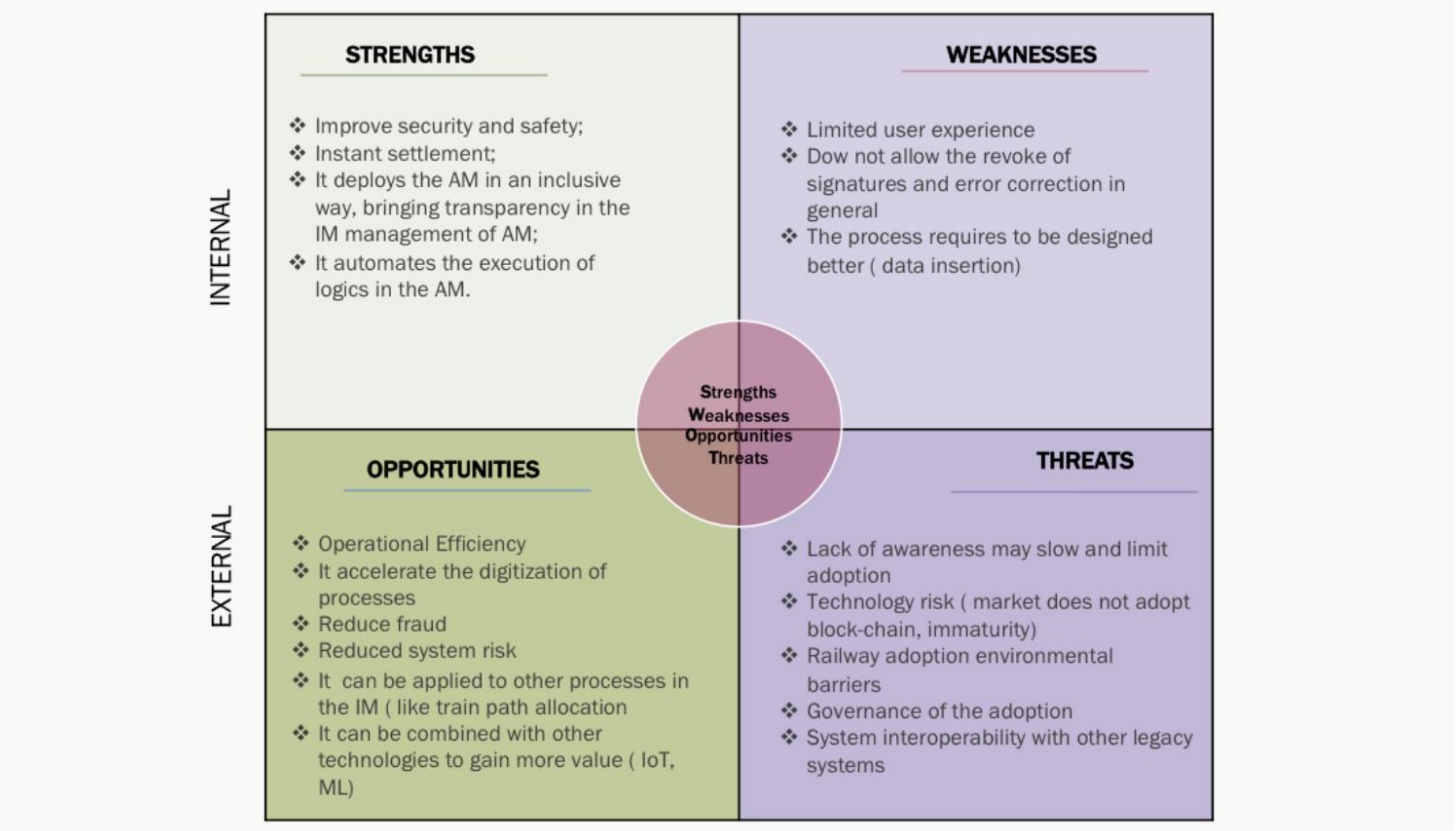

Figure 18: SWOT table of the final analysis of the PoC

IN2DREAMS

Td: Future Technical Challenges

- NETWORK
  - performance, scalability, integration and interoperabiity
- APP LAYER
  - revocation
  - data insertion
  - ux

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IN2DREAMS

Smart Contracts CHALLENGES

NOW (CONTEXT OF IN2DREAMS)

IMPROVE & ENHANCE

- Complement the digital transformation processes; transformation processes
- Simplify ownership tracking and certification of processes
- Allow the actors to build an ecosystem where they can exchange value without setting up complex governance rules before.

IN THE FUTURE

NEW MARKETS MODELS

- Create new business models;
- New economic models in parallel with existing.

Shift2Rail

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IN2DREAMS

IMPACT 1

In this context, the PoC for SC has revealed that this approach can contribute to innovation of IM processes for **one main reason**:

It slows **down cost** for programmed AM life-cycle **while** maintaining, even not increasing, the **safety** of the process.

IMPACT 2

The IM context is paradigmatic for application of DLT, since of its intrinsic complexity

Many actors, many roles, different systems not integrated (silos), need to improve efficiency and automation **but** well defined and stable procedures

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CONCLUSIONS

- **There is space** in the Railway Ecosystem, beyond cryptocurrencies and financial applications, to continue and try the «decentralization paradigm»
- The **potential opportunities** and challenges of deploying blockchain technology in AM and IM are **strongly related to sectorial issues** of enhancing safety, digital transformation, and simplification.
- The technology is still at the **embryonic stage AND THE** challenges ARE :
  - *performance and scalability,*
  - *integration with legacy infrastructures,*
  - *interoperability between different blockchains*.

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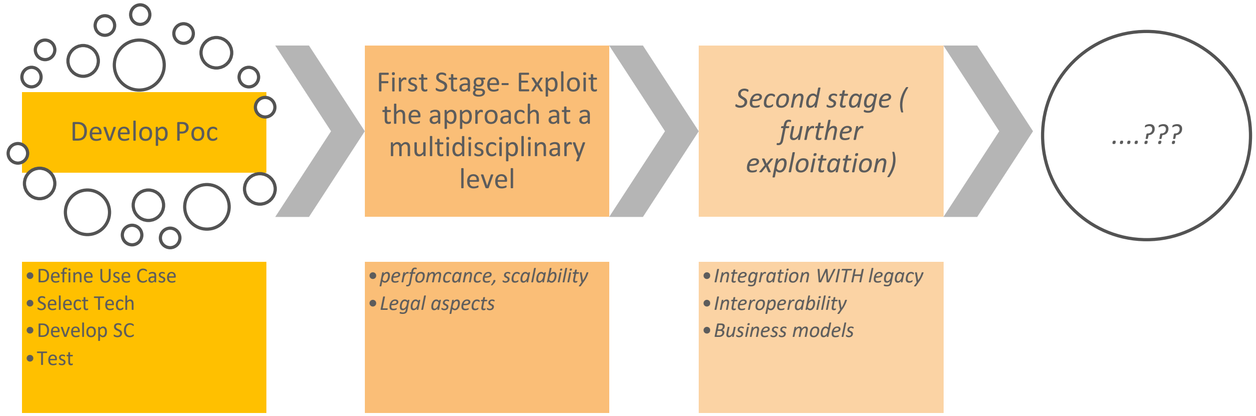
CONCLUSIONS

- **The required approach FOR continuing the work has to be multidisciplinary** since it has implication on rules, trust, economic aspects.



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IN2DREAMS

Knowledge extraction from Railway Asset Data

DAVIDE ANGUITA (UNIVERSITY OF GENOA)

IN2DREAMS Final Conference, Milan, 02.10.2019

WP5 contributors

- UNIGE - UNIVERSITÀ DEGLI STUDI DI GENOVA
- EE - EVOLUTION ENERGIE
- CEF - CEFRIEL
- KUL - KATHOLIEKE UNIVERSITEIT LEUVEN
- UKON - UNIVERSITAT KONSTANZ
- RFI - RETE FERROVIARIA ITALIANA

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IN2DREAMS

WS2 – WP5 Scope

- IN2DREAMS-WS2 will concentrate on defining IT **solutions** and **methodologies** for **business-secure decision support** in the field of **data processing** and **analytics** for railway asset management.

- The general aim is to study and proof the application of **smart contracts** in the railway ecosystems, by addressing also **legal** and **regulatory** implications, and advanced **visual** and **rule-based data analytics**, including **metrics** for **performance assessment**.

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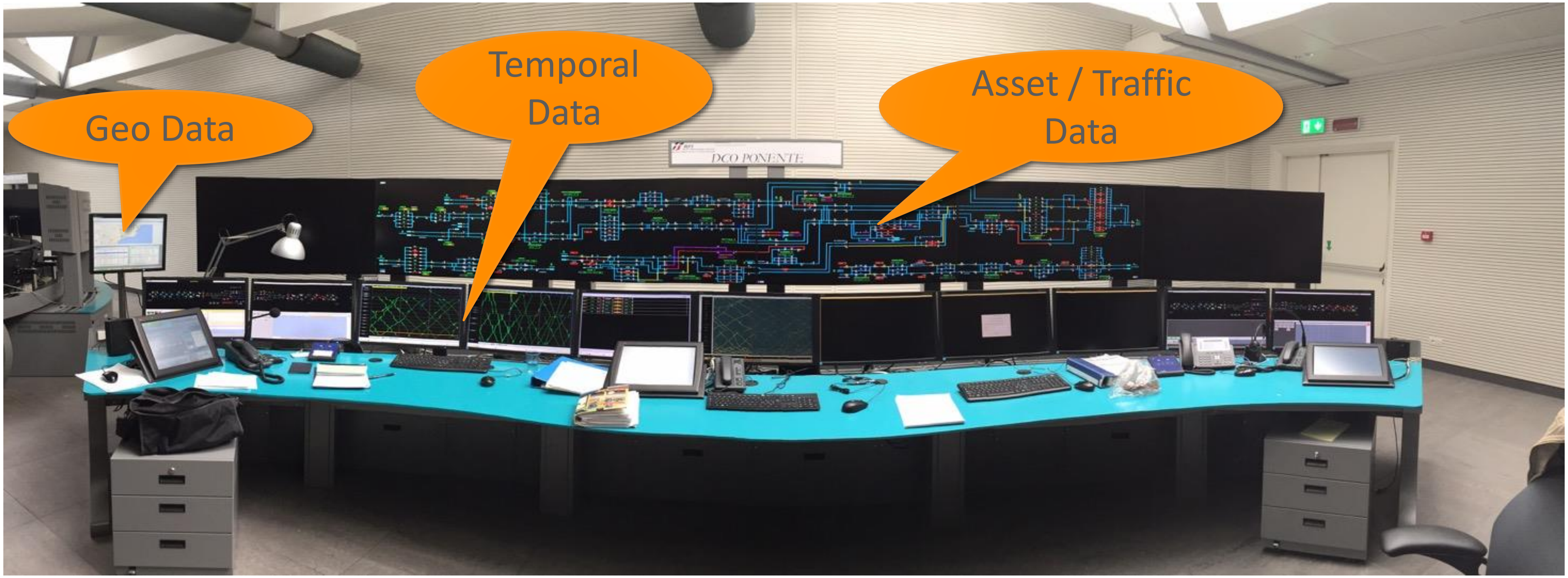
IN2DREAMS

WP5 – Asset data



Courtesy of RFI

Analytics: an easy task?

IBM Watson Analytics

Get business insights in minutes

Spot business trends and patterns easily on your desktop or iPad with automatic data visualization and guided analysis.

Try it for free

View demo (01:01)

Welcome to Azure Machine Learning

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Sign In

Not an Azure ML user? Sign up here

Google's Newly Launched Cloud AutoML Let's You Build Models without Coding

AVBYTES BUSINESS INTELLIGENCE MACHINE LEARNING

PRANAV DAR , JANUARY 18, 2018 / 3

SHARE

«How Far Can We Trust Big Data Analytics?»

Mike Ames, Director of Analytics, SAS
Nigel King, Vice President of Applications Development, Oracle

Big Data Analytics Conference, Tuesday, October 21, 2014, San Jose, California 95113, United States

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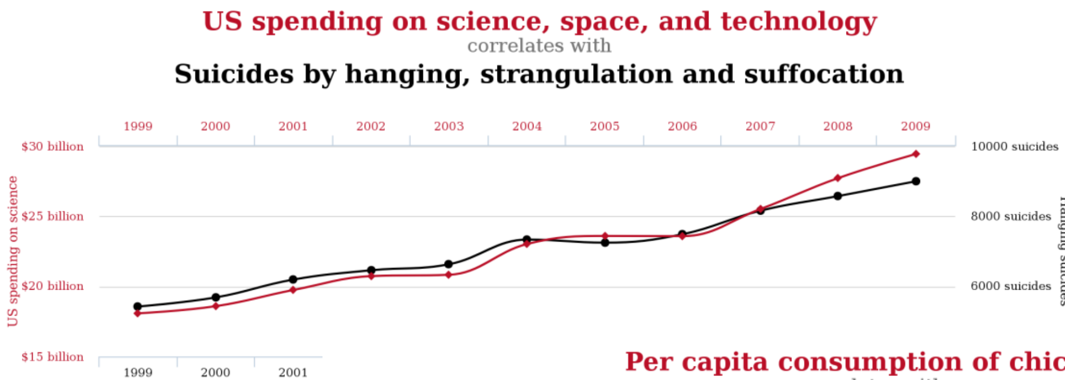
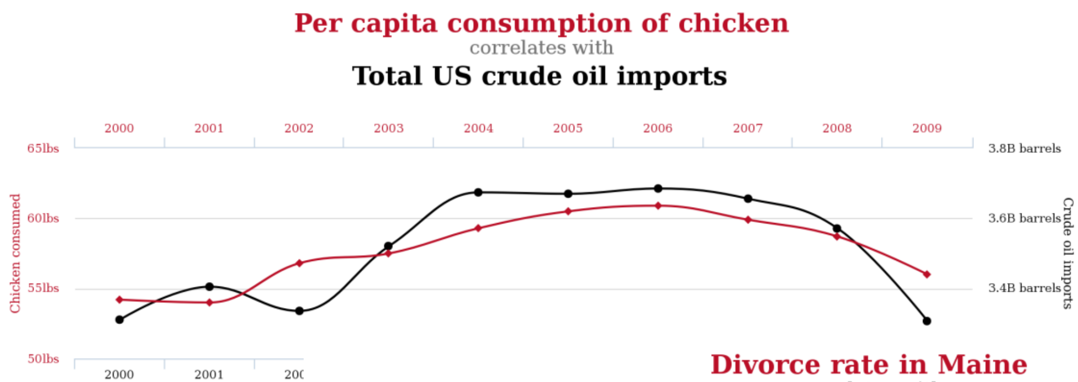
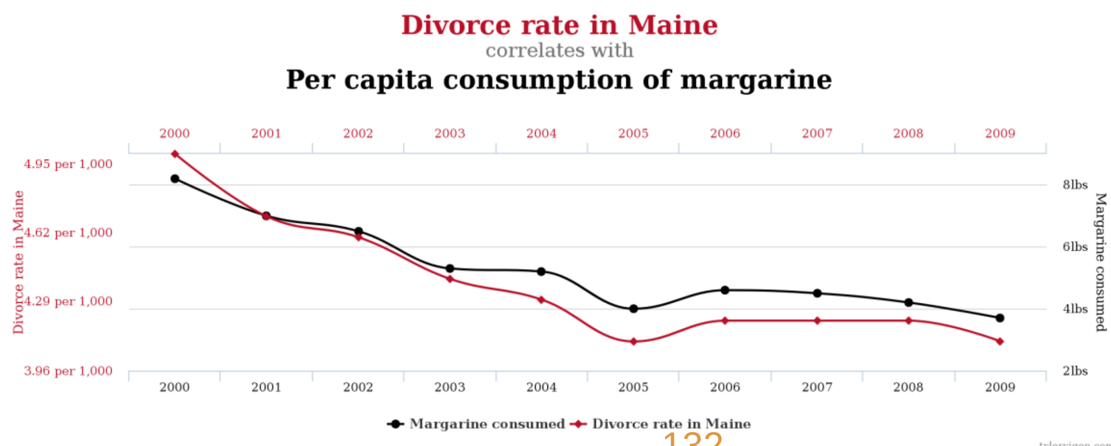
IN2DREAMS

Data analytics can correlate any data…







Source: Spurious Correlations

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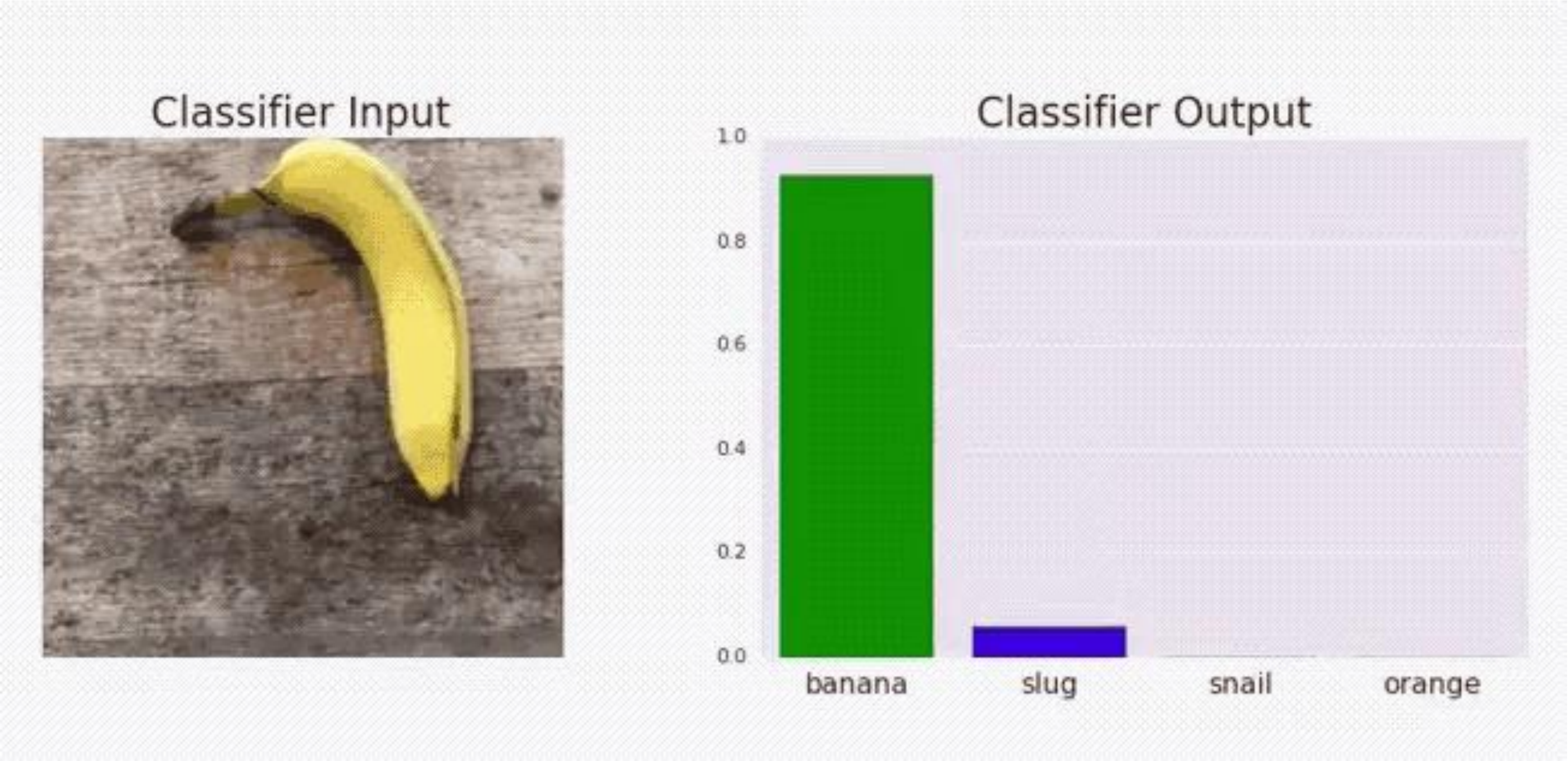
AI can be unreliable...



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WS2 – WP5 Scope

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- The general aim is to study and proof the application of **smart contracts** in the railway ecosystems, by addressing also **legal** and **regulatory** implications, and advanced **visual** and **rule-based data analytics**, including **metrics** for **performance assessment**.

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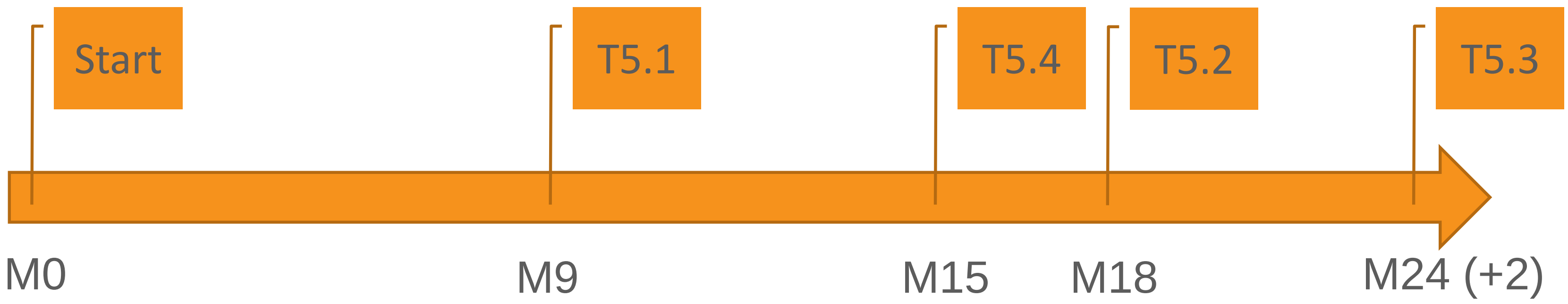
WP5 timeline



- T5.1 - Definition of data analytics scenarios
- T5.4 - Methods for rule-based and visual analytics knowledge extraction
- T5.2 - Metrics and tools for data analytics algorithms assessment
- T5.3 - Development and Testing of knowledge extraction solutions

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- **Definition of data analytics scenarios**

- **Objective:** definition of a **set of analytics scenarios** that will be used as **case studies** for the development of data analytics algorithms and metrics for their assessment

- **Result**: 7 analytics scenarios identified

IN2DREAMS

WP5 - Analytics Scenarios

CROSS-SCENARIOS

1. Visual analytics in Control Center
2. Marketplace of Data and Data Monetization (WP4 IN2DREAMS and IN2SMART connections)

SPECIFIC SCENARIOS

3. Track Circuits state monitoring (ASTS as advisor from IN2SMART)
4. Train Delays and Penalties (extension of IN2RAIL)
5. Restoration Time (STRUKTON as advisor from IN2SMART)
6. Switches (STRUKTON as advisor from IN2SMART)
7. Energy Consumption (from WS1)

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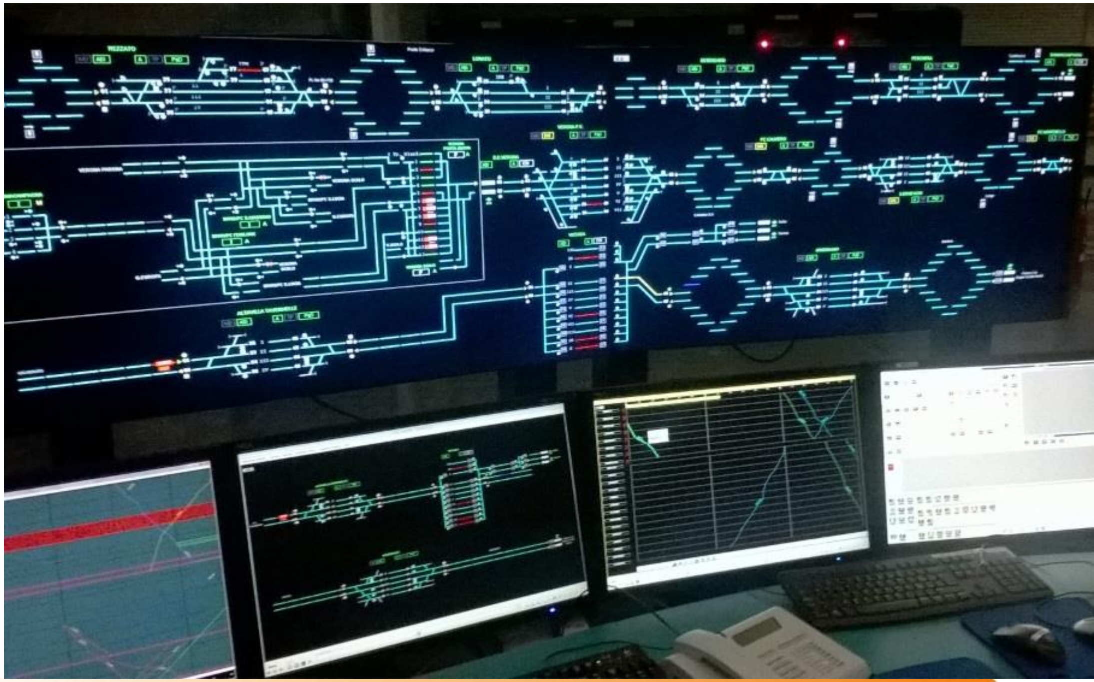
Scenario 1

Improving Information Visualization and Operator Interaction in the Railway Control Center

- Information already displayed
- Operators interaction
- Result of Data Driven Models
- Result of Rule Extraction Methods
- Quality of the predictions



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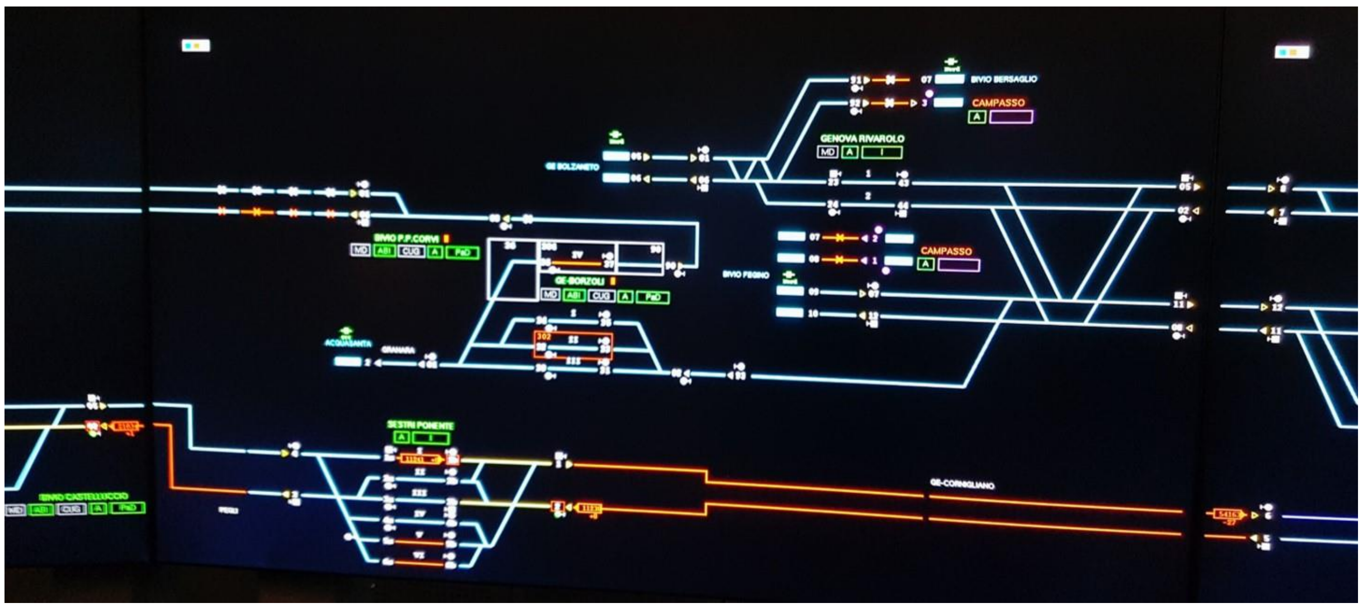
Scenario 1

Objectives

1. Conflict resolution
2. Alert Management and prioritization
3. Awareness of the operator



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Marketplace of Data and Data Monetization

Data Lakes

Blockchain

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Scenario 2

- **Background**
  - Blockchain allows the creation of a “marketplace” of the data inserted/exploited in data lakes by the different actors
- **Goals**
  - Use the Blockchain for certifying the access/injection/use of the data (WP4)
  - Use of the Smart Contract to associate a value to the data based on IF-THEN-ELSE rules (WP4)
    - Payments with Bank
    - Payments with Cryptocurrencies
  - **Insert predictive models inside the Smart Contract (WP5)**
    - historic archive of transactions -> automatic evaluation of value of a new datasource or future value of an already available source of information
    - Estimate the quality of the predictive model
- Too futuristic for actual POC
- Worth exploring (WP4 & WP5) for potentially disruptive impact on B2B data “marketplace” creation

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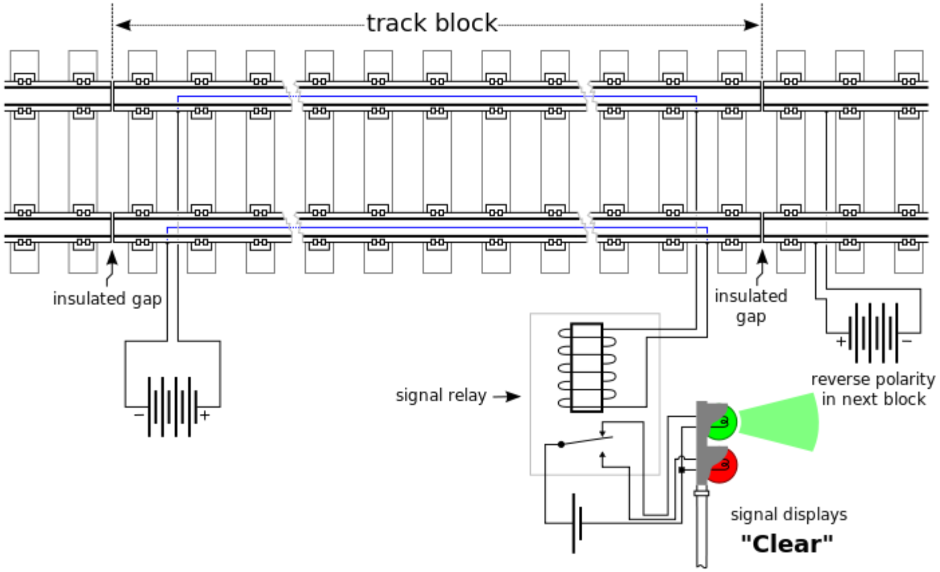
Track Circuit State Monitoring (from IN2SMART)

- TC are used to detect the occupation of a section of the track
- Problem: false occupation, failure, etc.



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IN2DREAMS

Scenario 4

Train Delay forecasting

- Developing interpretable models
- Handling change in the timetable
- Taking into account the costs of a delay (e.g. misprediction -> penalties)

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Scenario 5

Prediction of Restoration Time (Maintenance)

- **Information collection**:
  - **Weather condition:** data retrieved from the national weather services;
  - **Maintenance/Repair actions**: historical datasets about maintenance/repair activities, including their duration;
  - **Malfunctions:** historical datasets about failures/malfunctions.
- **Goal**: estimating the time needed to restore the asset in operational conditions.

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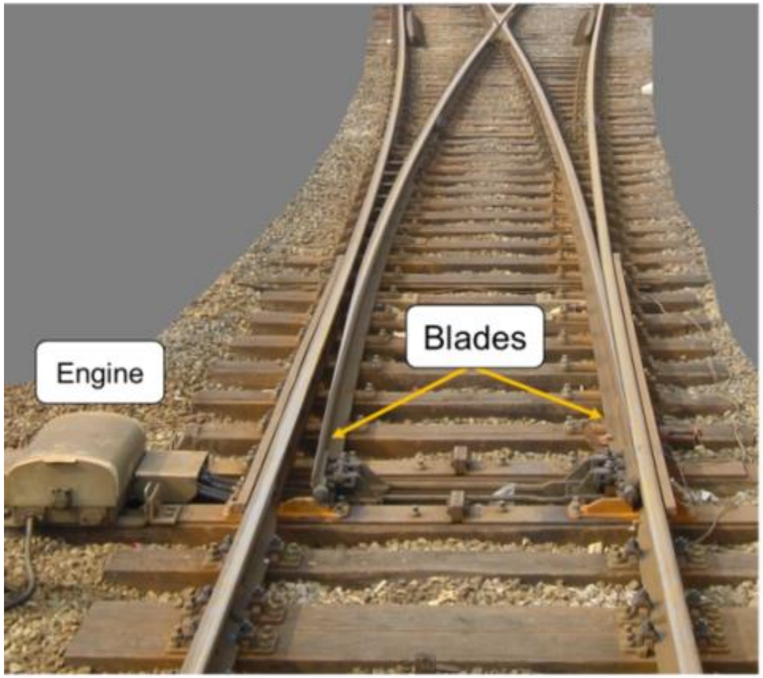
Prediction of Switch failure



- Complex electro-mechanical system
- Exposed to harsh conditions
- POSS:
    - SR monitoring system
    - Engine current curve during switch movement
- Not all failures can be detected
- Weather conditions data

Train energy consumption model

- **Goal**: building an interpretable and reliable data-driven train power consumption forecast model and use this prediction to compare the results to the real data.
- **Impact**: better understanding of the system and better management of energy.

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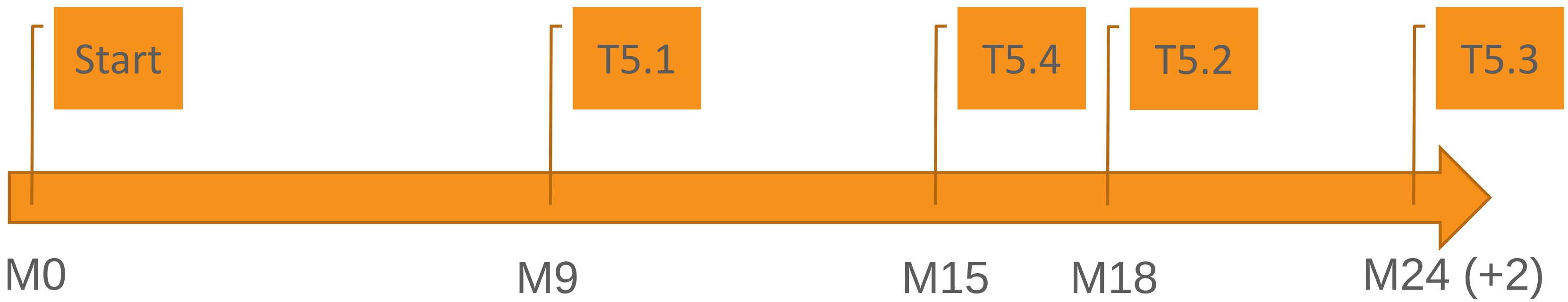
IN2DREAMS

WP5 timeline



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- T5.4 - Methods for rule-based and visual analytics knowledge extraction
- T5.2 - Metrics and tools for data analytics algorithms assessment
- T5.3 - Development and Testing of knowledge extraction solutions

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IN2DREAMS

Task 5.4

- **Methods for rule-based and visual analytics knowledge extraction**

- **Objective:** enhance the capability of **understanding information content** included in (railway asset) data

- **Results**: innovative application of **visual analytics** tools, innovative application of **rule-based analytics** tools

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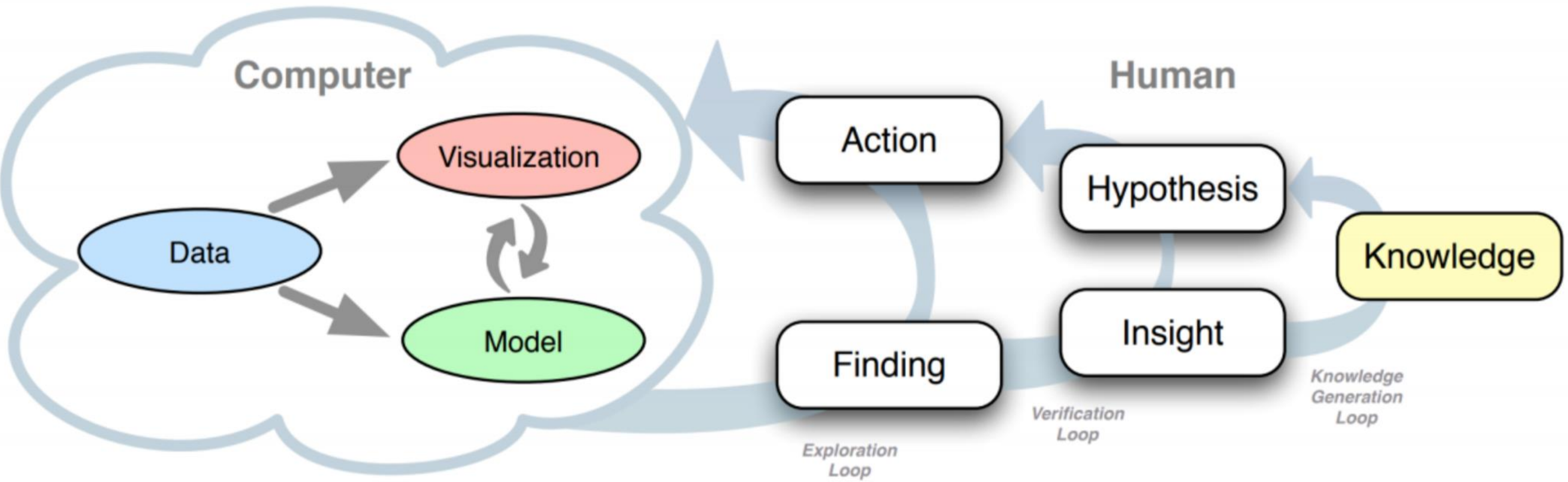
IN2DREAMS

The Knowledge Generation Model for Visual Analytics



Courtesy of University of Konstanz

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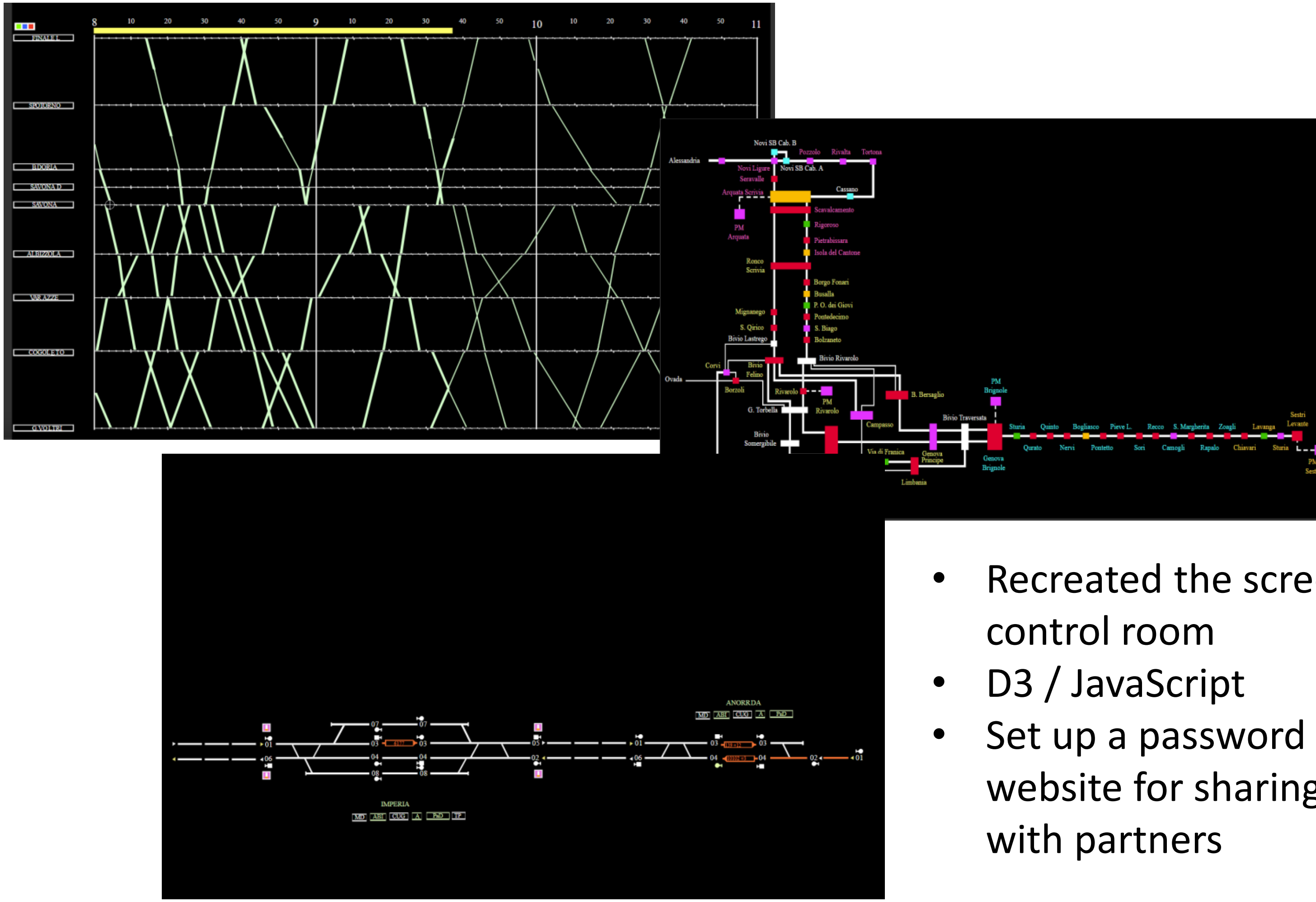
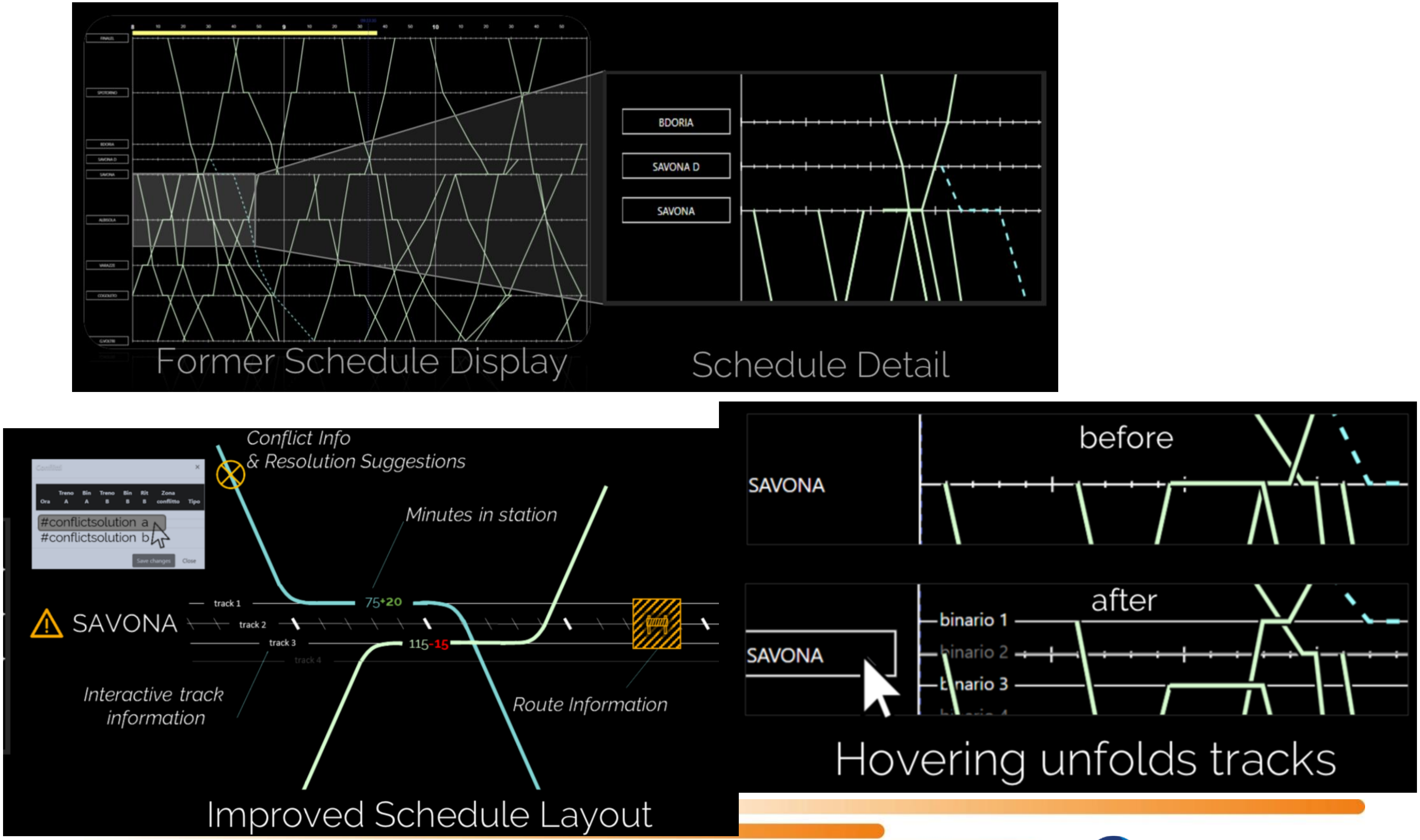
Control room mockup



- Recreated the screens of the control room
- D3 / JavaScript
- Set up a password protected website for sharing with partners

IN2DREAMS

Objective 1 - Conflict Resolution



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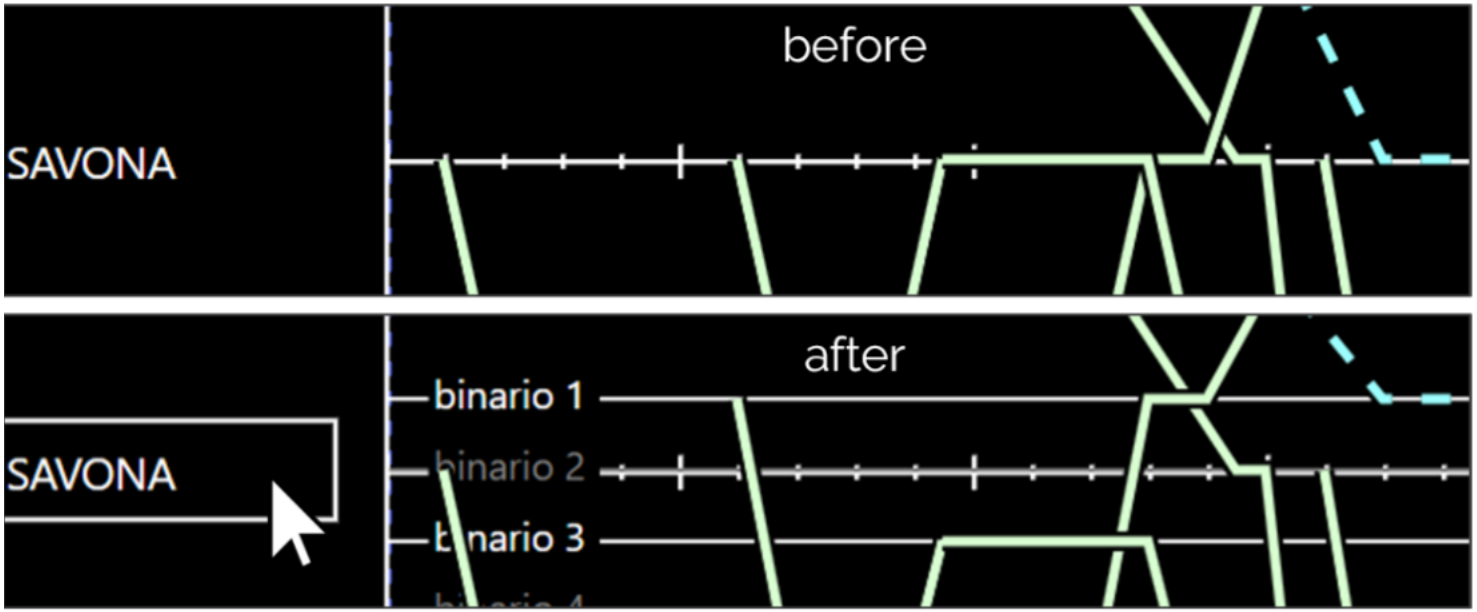
IN2DREAMS

Some details (1)

OLD

NEW



Improved schedule view with interactive platform visualization and adapted layout

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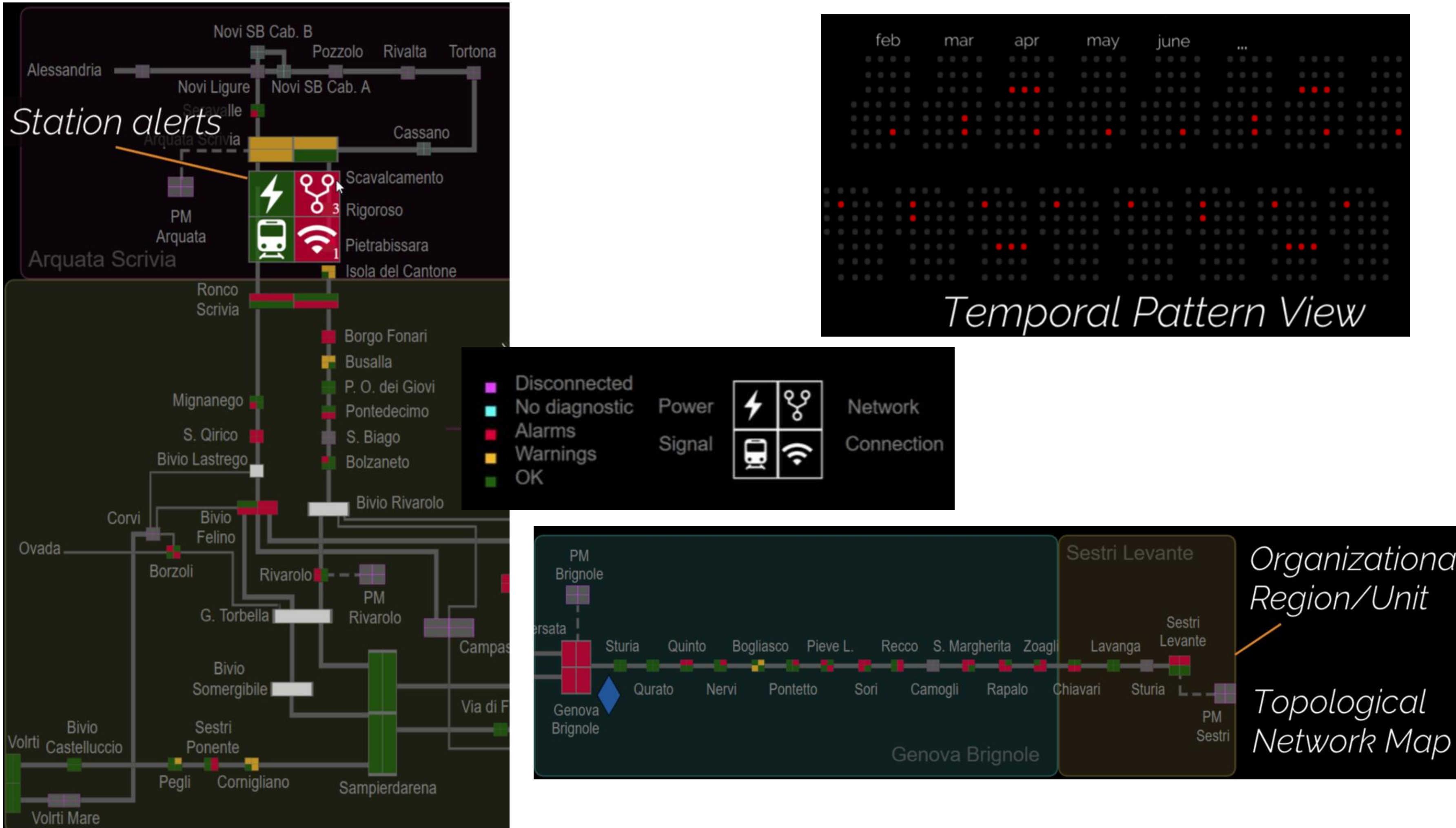
IN2DREAMS

Objective 2 - Alert Management and Prioritization System



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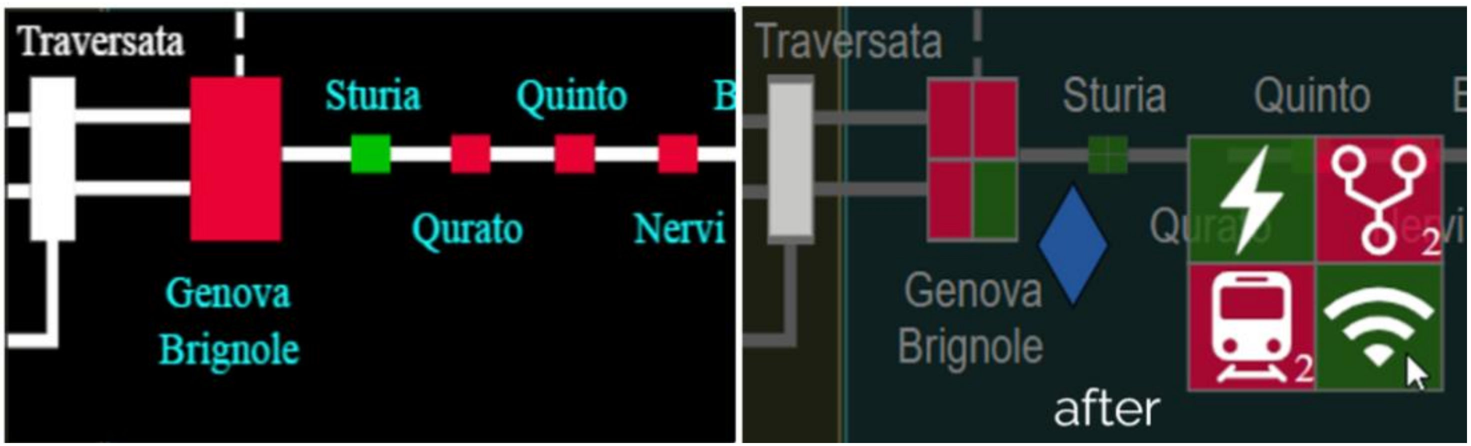
Some details (2)



OLD NEW

Added contextual icons and semantic alert view. The numbers relate to the amount of alerts present at this station, the color to their severity.

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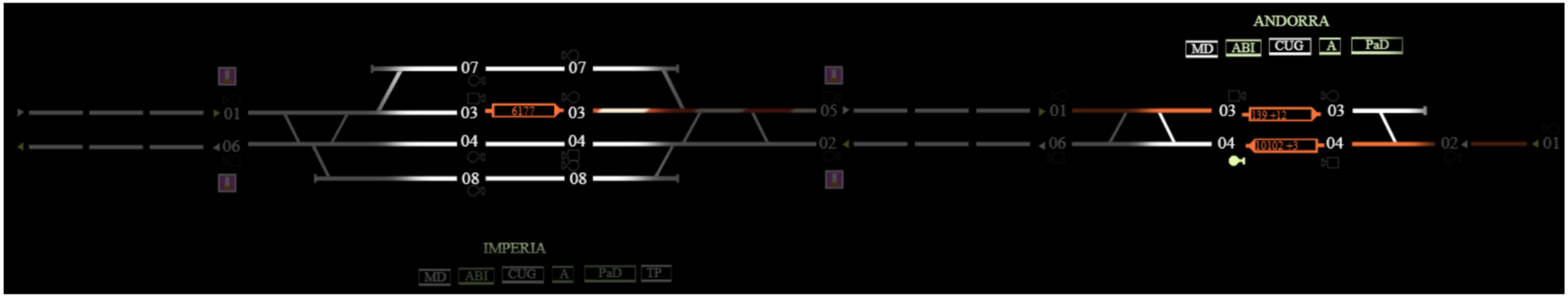
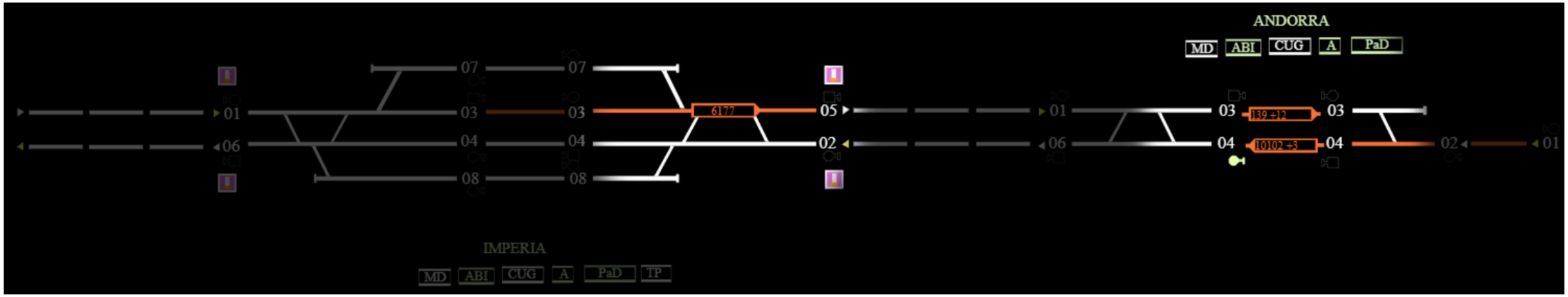
Objective 3 - TMS Improvement and Attention Steering for Operators





Reduction of non-important symbols

«Glowing effect» to keep the operator focused while maintaining the overview of the system as well as keeping the spatial referencing

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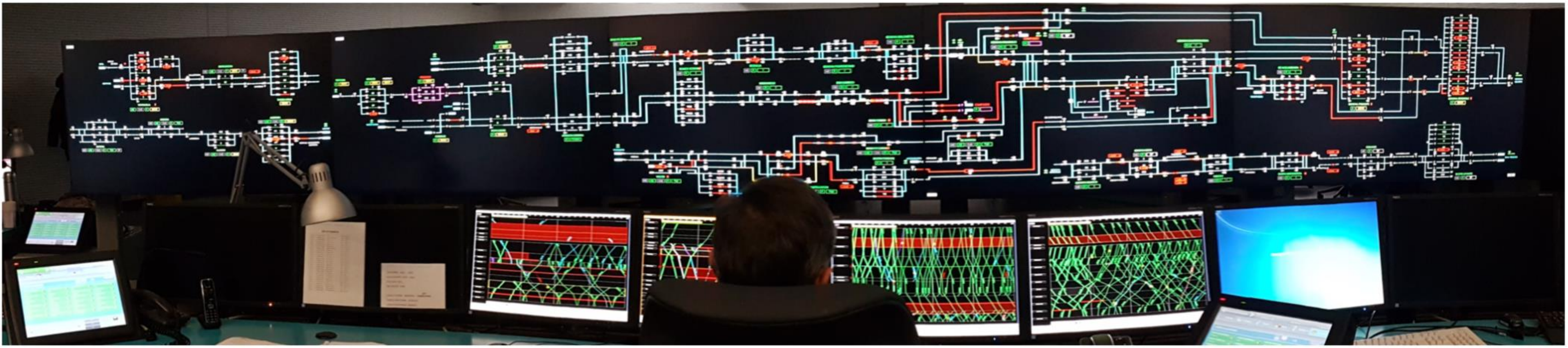
Validation

Visualization For Train Management: Improving Overviews in Safety-critical Control Room Environments

Eren Cakmak Giuliano Castiglia Wolfgang Jentner Juri Buchmüller Daniel A. Keim

University of Konstanz, Germany*



4th International Symposium on Big Data Visual and Immersive Analytics

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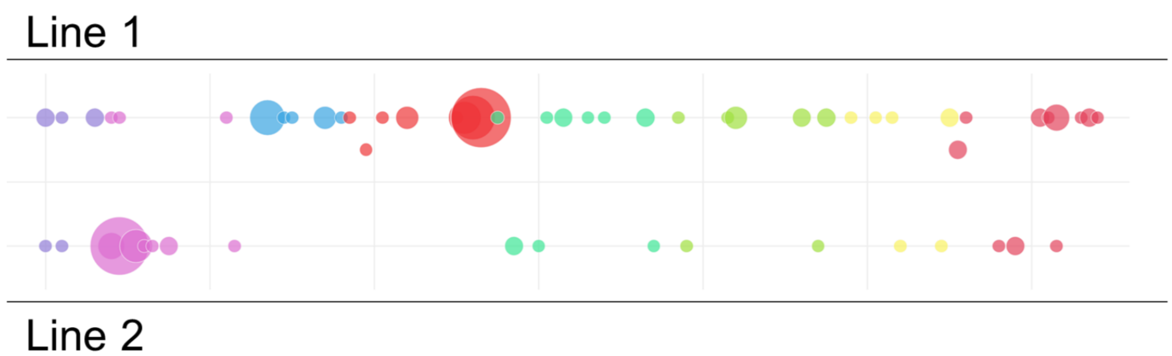
Track circuits visual analytics



Bubble plot of alarms occurrences along the railway lines. Three different kinds of information are represented: geographical (bubble distribution) quantitative (bubbles dimension) and categorical (the color represents the zone to which an asset belongs).

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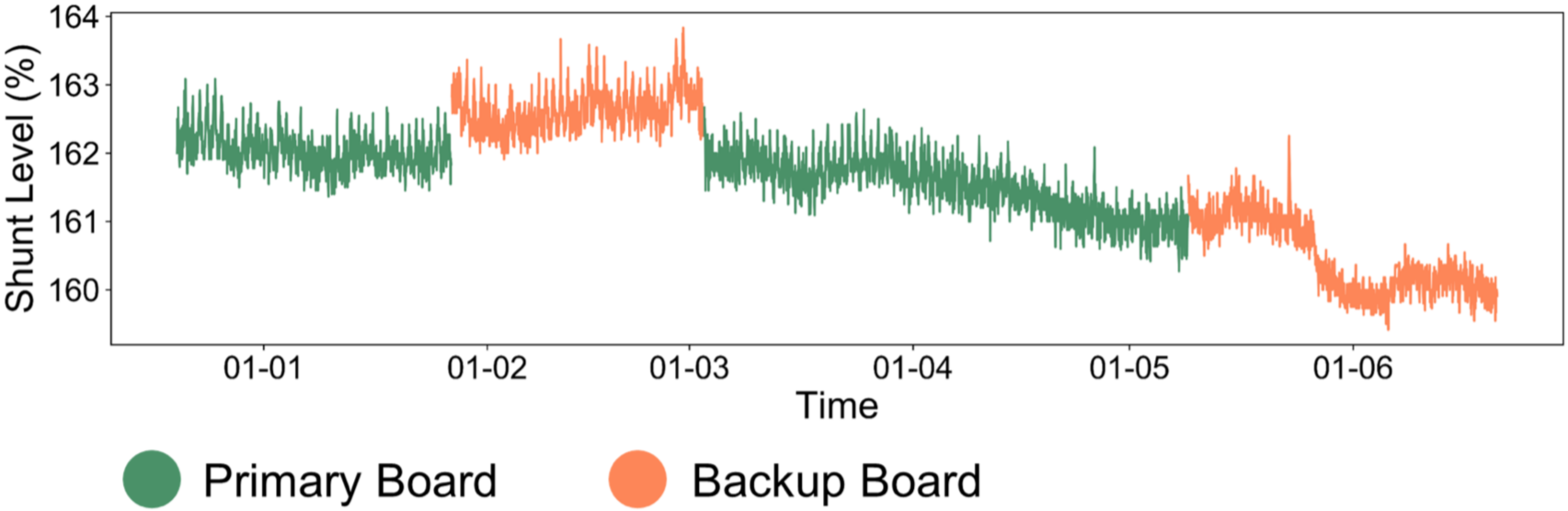
Track circuits visual analytics



Example of a possible representation of the Shunt Level trend over time after the data processing step: color informaton is added to identfy which board is actve in a specific moment

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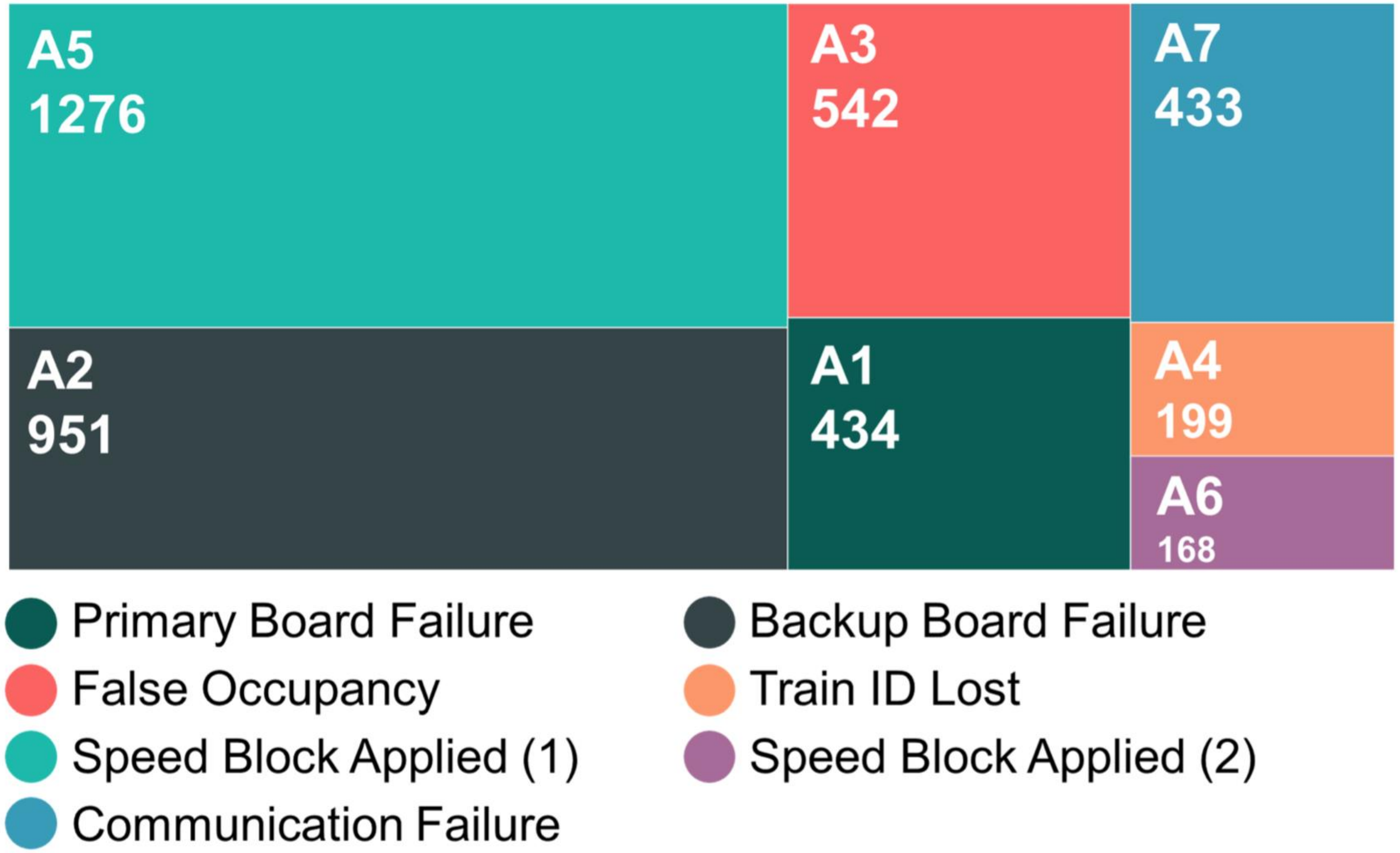
Track circuits



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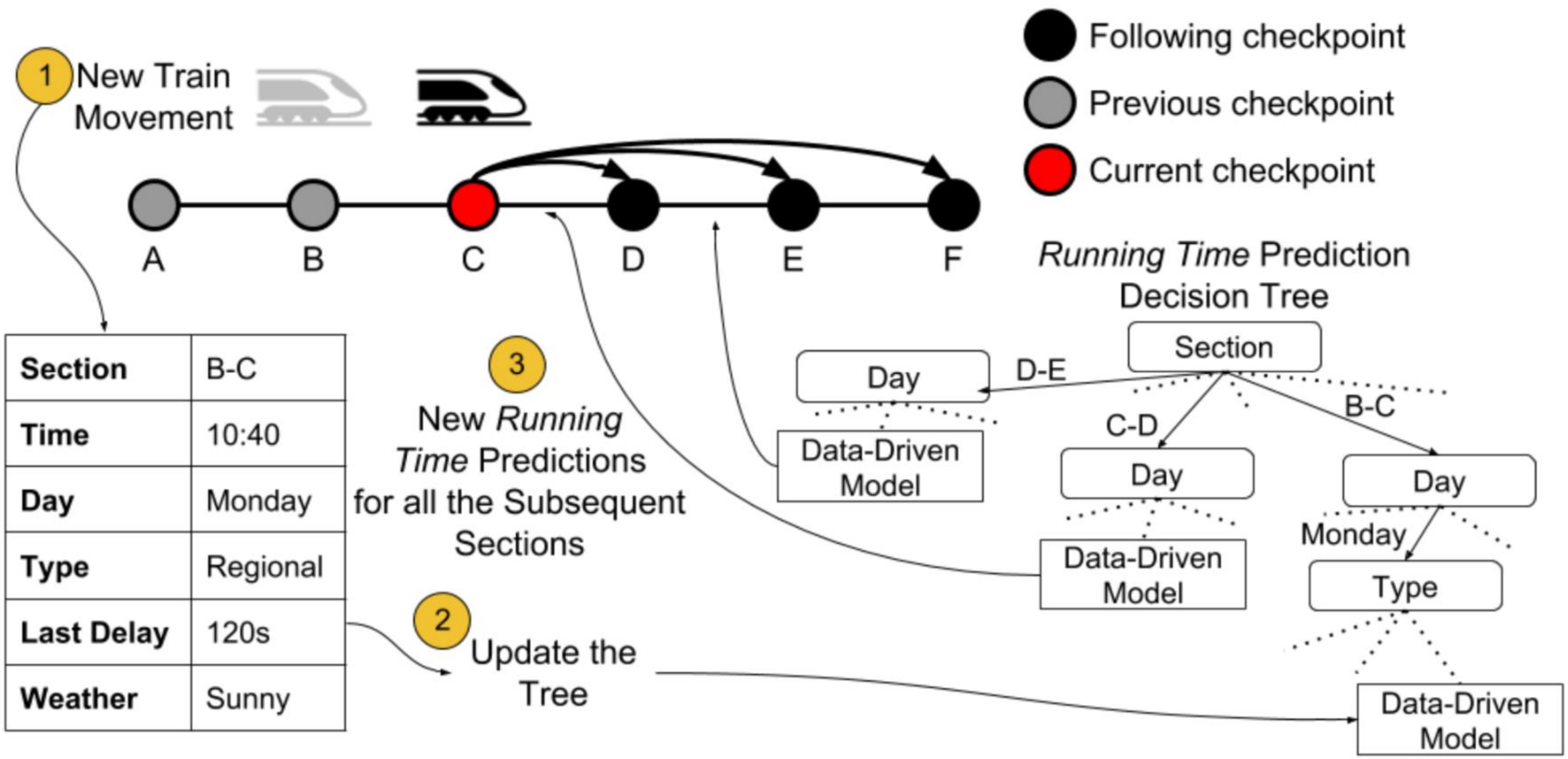
Rule-based analytics



Section	B-C
Time	10:40
Day	Monday
Type	Regional
Last Delay	120s
Weather	Sunny

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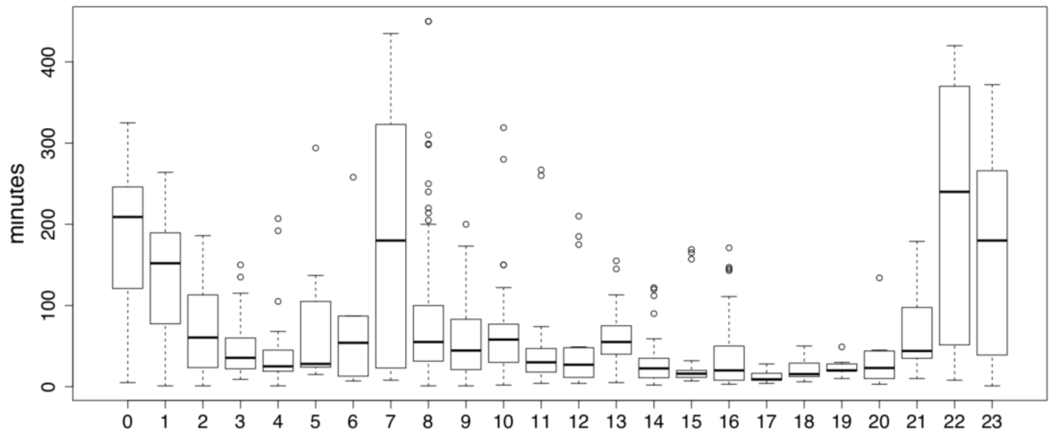
Scenario 3: Restoration time

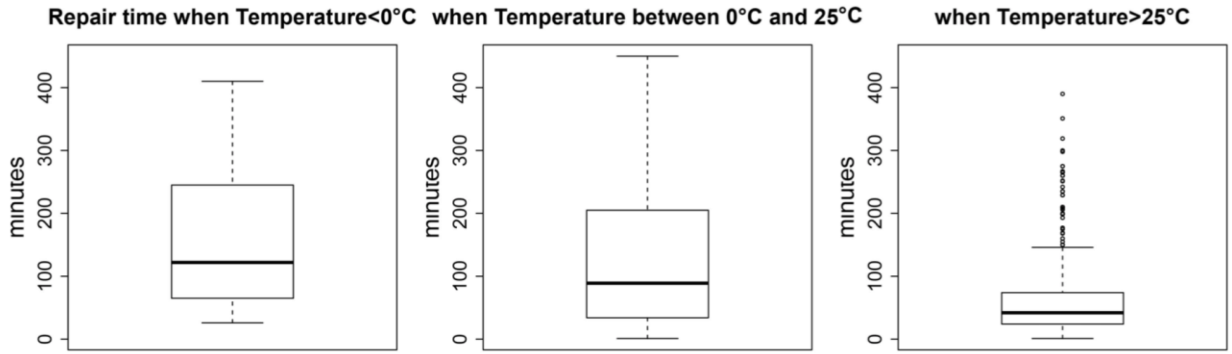
Strukton: maintenance works from 01-01-2010 to 31-12-2015 (17243 observations, 47 variables)

RFI: maintenance works from 01-06-2017 to 31-01-2018 (4945 samples and 13 variables)

Rule-based analytics



Repair Time as a function of «Hour of the day»



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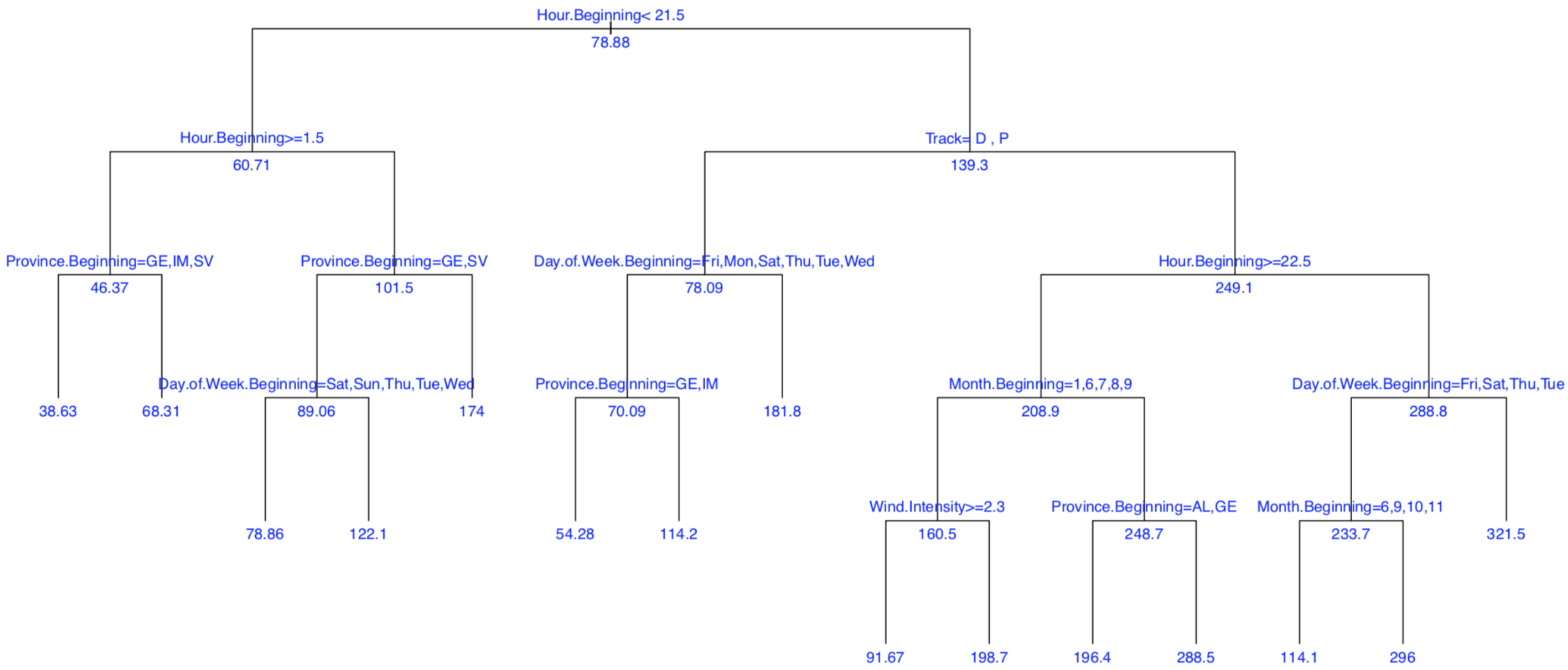
Rule-based analytics

Pruned Regression Tree for Repair Time



Learning a Decision Tree
User has access to the model «reasoning»
(how the model is taking decisions?)

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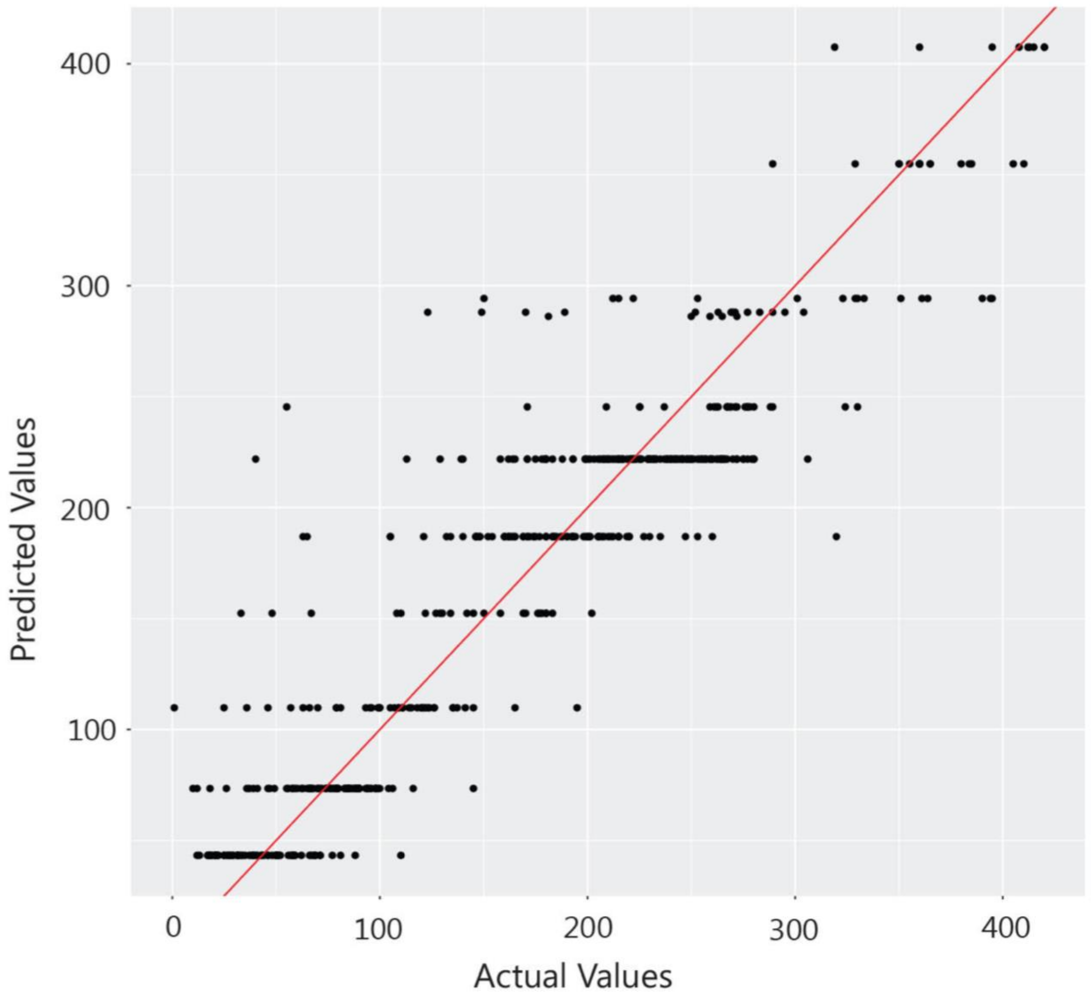
Rule-based analytics



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More results in…

- L. Oneto, I. Buselli, A. Lulli, R. Canepa, S. Petralli, and D. Anguita. *A dynamic, interpretable, and robust hybrid data analytics system for train movements in large-scale railway networks*. International Journal of Data Science and Analytics, 2019.
- R. Spigolon, L. Oneto, D. Anastasovski, N. Fabrizio, M. Swiatek, R. Canepa, and D. Anguita. *Improving railway maintenance actions with big data and distributed ledger technologies*. In *INNS Big Data and Deep Learning (INNSBDDL)*, 2019
- L. Oneto, I. Buselli, P. Sanetti, R. Canepa, S. Petralli, and D. Anguita. *Restoration time prediction in large scale railway networks: Big data and interpretability*. In *INNS Big Data and Deep Learning (INNSBDDL)*, 2019
- L. Oneto, I. Buselli, A. Luli, R. Canepa, S. Petralli, and D. Anguita. *Train overtaking prediction in railway networks: a big data perspective*. In *INNS Big Data and Deep Learning*, 2019
- U. Schlegel, W. Jentner, J. Buchmueller, E. Cakmak, G. Castiglia, R. Canepa, S. Petralli, L. Oneto, D. A. Keim, and D. Anguita. *Visual analytics for supporting conflict resolution in large railway* networks. In INNS Big Data and Deep Learning, 2019
- A. Lulli, L. Oneto, R. Canepa, S. Petralli, and D. Anguita. Large-scale railway networks train movements: a dynamic, interpretable, and robust hybrid data analytics system. In *IEEE International Conference on Data Science and Advanced Analytics (DSAA)*, 2018

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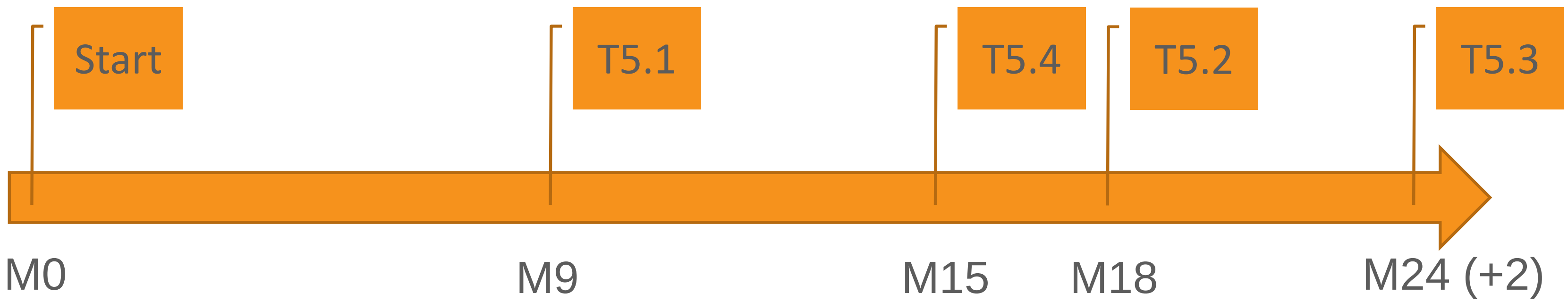
WP5 timeline



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Task 5.2

- **Metrics and tools for data analytics algorithms assessment**

- **Objective:** assessing the risk associated with the usage of data-driven algorithms, considering also legal aspects

- **Results**: tools for assessment of predictive algorithms, identification of legal challenges

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Legal assessment «metrics»

- Algorithmic transparency
- Algorithmic accountability
- Right to an explanation
- Human-in-the-loop

Impact on legal procedures

C.Ducuing, L.Oneto, R.Canepa, «Fairness and Accountability of Machine Learning Models in Railway Market: are Applicable Railway Laws up to Regulate Them?» European Symposium on Artificial Neural Networks and Machine Learning, 2019.

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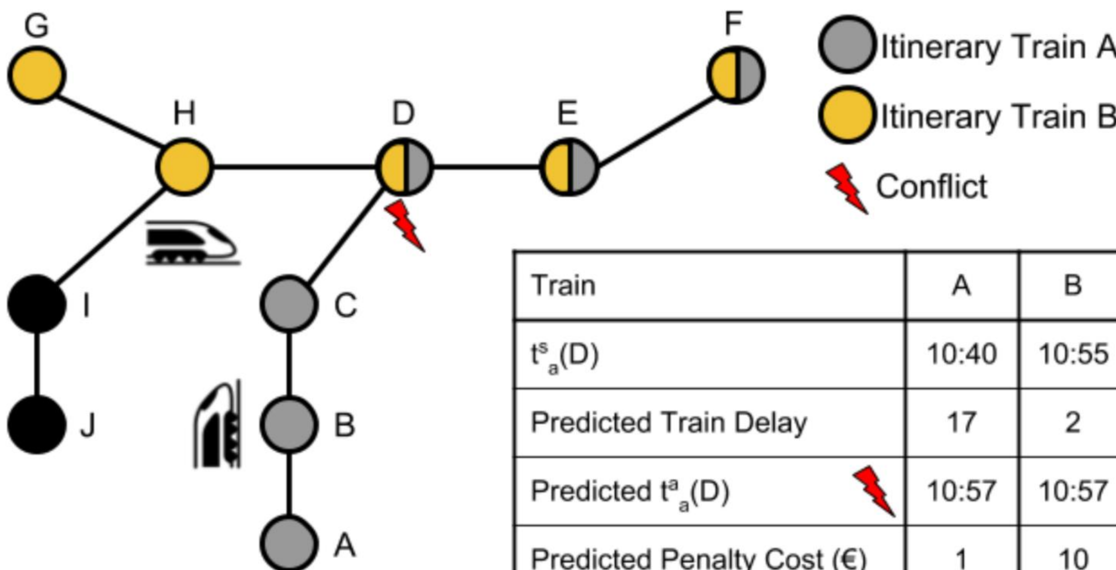
Data analytics metric



Train	A	B
$t^s_a(D)$	10:40	10:55
Predicted Train Delay	17	2
Predicted $t^a_a(D)$	10:57	10:57
Predicted Penalty Cost (€)	1	10

Impact on costs

Train Delay vs. Penalty Costs

Penalty Cost

$$P = P_U \sum_{j \in \mathcal{I}} m_j r_j C_T C_N C_D$$

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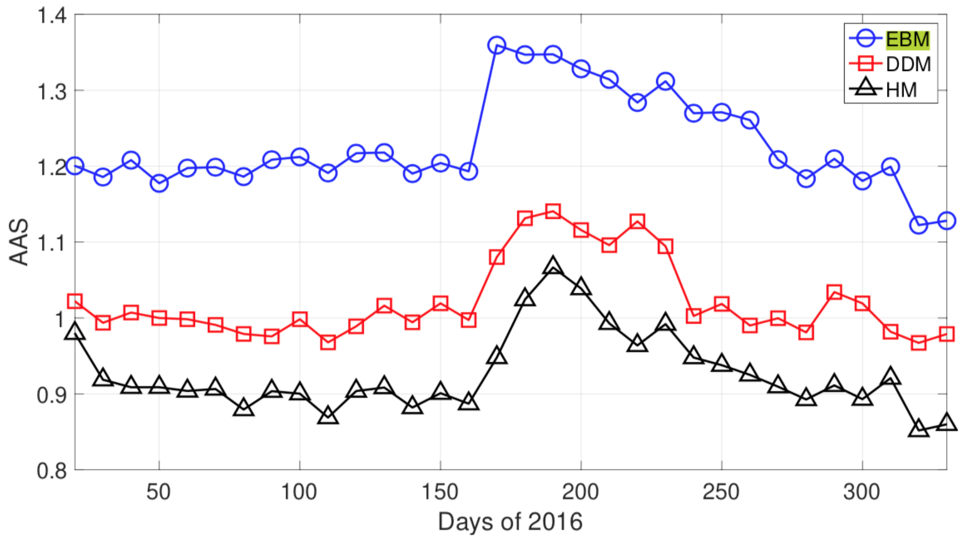
IN2DREAMS

Data analytics metric



EBM = Empirical Based Mode
DDM = Data Driven Model
HM = Hybrid Model

AAS = Average Accuracy delay prediction on all Sections

Up to 20% improvement

	EBM	*DDM*	*HM*
AAP Regional	4.15	3.01	**2.49**
AAP High Speed	0.21	0.15	**0.14**
AAP Freight	0.11	0.09	**0.08**
AAP	4.44	3.05	**2.71**

AAP = Average Accuracy of Penalty Costs predictions

Up to 50% improvement

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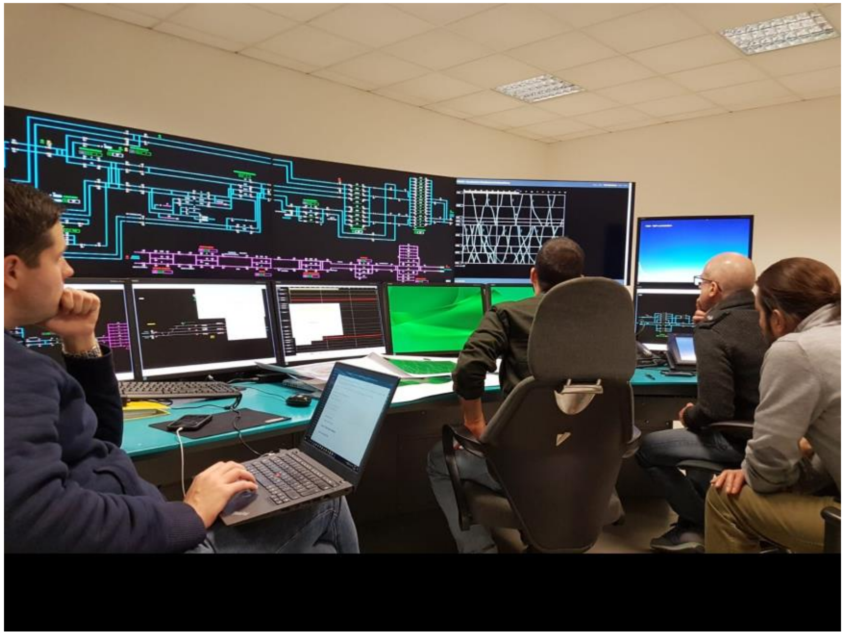
Analytics assessment

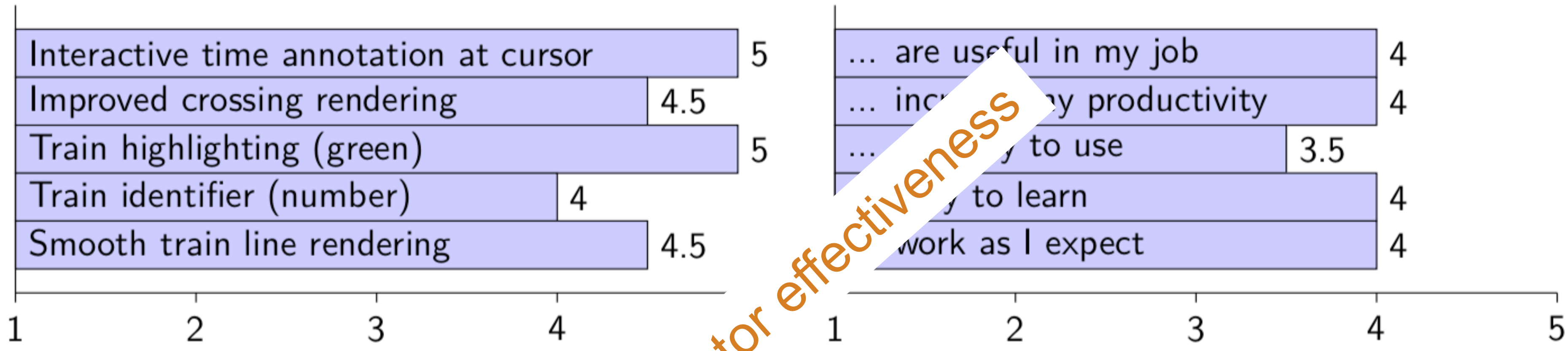


Approaches validated by RFI

(RFI Control Center test, Genoa, Italy)

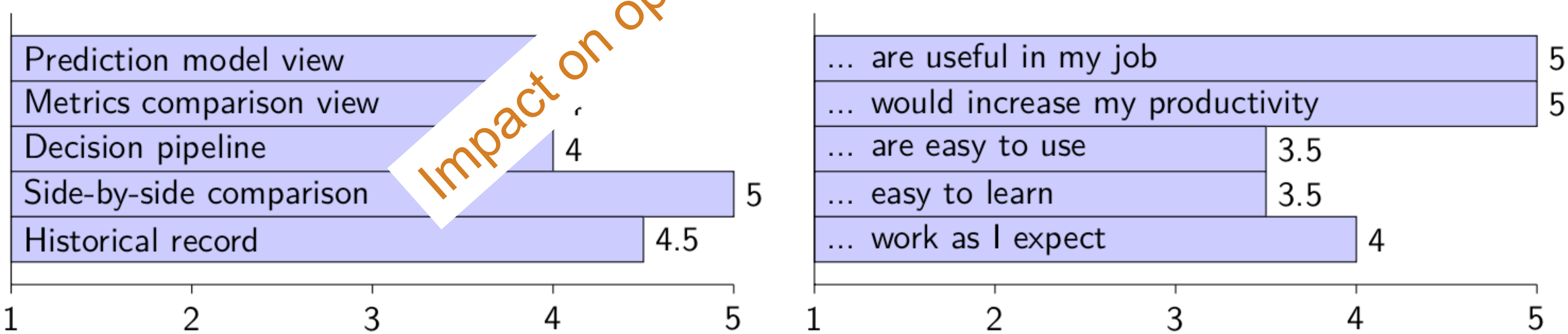
IN2DREAMS

Visual analytics metrics



Impact on operator effectiveness

Revis   **n Schedule View**



Revised Conflict Resolu on View

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Task 5.3

- **Development and Testing of knowledge extraction solutions**

- **Objective:** demonstrate the achievements of previous tasks

- **Result**: a POC combining the capabilities of a Distributed Ledger Technology implementation (from WP4) with a highly-transparent data-driven prediction algorithm for maintenance process operations

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WS2 Demonstrator

- Demonstrator for WS2 (both WP4 and WP5)
  - CEFRIEL -> handling maintenance with blockchain
  - UNIGE -> predicting restoration time due to maintenance
  - UKON -> visualisation in the control center (visualisation for maintainers and train dispatchers)
  - RFI -> test room (Control Center)

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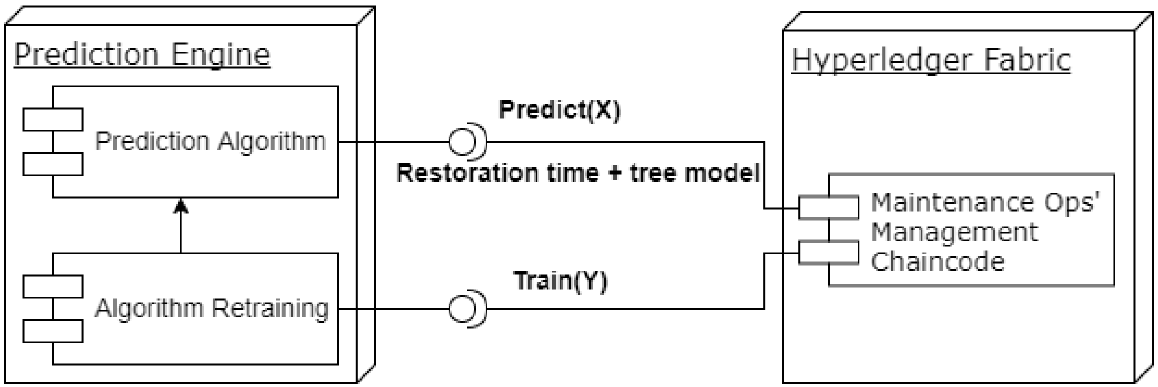
WS2 Demonstrator

From WP5

From WP4



Architecture

IN2DREAMS

Thank you!

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