NEWSLETTER

AUGUST 2019

IN2DREAMS

Shift2Rail

CONTENT

Foreword

You are reading the last newsletter of the IN2DREAMS (INtelligent solutions 2ward the Development of Railway Energy and Asset Management Systems in Europe) project, were you will learn about what the project has achieved during its 26-month duration from a technological point of view. Through the various developments that are being described, you should also get an idea of what's still to come through the work that will be carried out within the complementary projects of Shift2Rail, more specifically the ones related to cost-efficient and reliable infrastructure linked to the third Innovation Programme (IP3).

To find out more about IN2DREAMS and its objectives, to access the public deliverables and to get a closer look at various publications, please visit our website on **www.in2dreams.eu**

Project Scope & Structure

The 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.

The IN2DREAMS project addressed these challenges through two distinct work streams, namely:

- Work Stream 1 (WS1): Management of Energy-related Data;
- Work Stream 2 (WS2): Management of Asset-related Data.

IN2DREAMS developed and demonstrated a modular cloud-based open data management platform (ODM) facilitating ubiquitous support of both energy and asset services. WS1 provides energy metering services through a dynamically reconfigurable platform offering improved reliability, ease of monitoring and on-the-fly optimisation for the entire railway system. This includes a heterogeneous secure and resilient telecommunication platform comprising both wireless and wireline technologies converging energy and telecom services.

This infrastructure interconnects a plethora of monitoring devices and end-users to the railway control centre and includes an ODM platform for data collection, aggregation and analysis, able to scale with the railway operators' needs. This platform is non-intrusive, exploiting advanced signal processing and intelligent learning algorithms. Within WS2, IN2DREAMS concentrated 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 was 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.

From the diagram below, you can see the Work Packages that are associated to each Work Stream and in the next pages you will get an overview of the work that was carried out in each technical WP, highlighting the main results and conclusions.

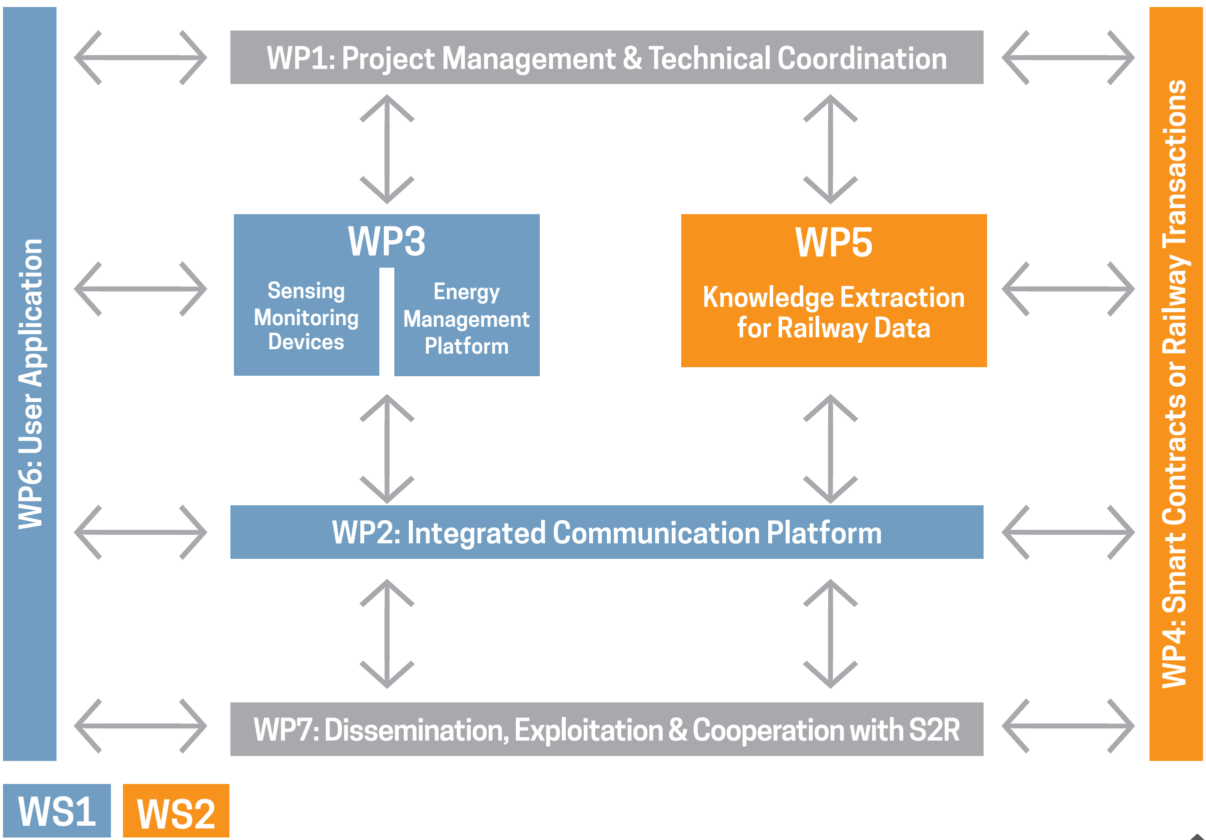


FIGURE 1 — IN2DREAMS project structure

Integrated Communication Platform

ICT platforms for future railway systems are expected to support a wide range of applications with highly variable performance attributes covering both operational and end-user service requirements. These platforms are expected to offer services ranging from delay sensitive video to infotainment services, and from best effort applications to ultra-reliable ones such as M2M (Machine-to-Machine) communications. An important consideration in the design of these platform is the very high mobility of train transportation systems beyond 2020 that in many cases may exceed 200 km/h. In addition to high mobility scenarios, connectivity for zero to low mobility cases (interconnecting devices at stations and substations) must be also supported. Other applications, such as remote maintenance of rolling stock and remote processing will have central role in future railway platforms.

In response to these challenges, an advanced communication platform was proposed, enabling connectivity between a variety of monitoring devices and computational resources through a heterogeneous network infrastructure comprising optical, Wi-Fi, LiFi and LTE technologies. One of the first problems that had to be addressed was associated with the optimal design of the cabin railway communication system. The IN2DREAMS project addressed this problem through the development of a novel modelling framework based on Mixed Integer Linear Programming.

FIGURE 2 — Example of an on-board multi-technology access network

To construct this model, the generic topology of Figure 2 has been considered where traffic source points, named test points, are placed. Each test point can either represent a passenger or a sensing/monitoring device generating a discrete/ continuous traffic distribution according to the desired planning scenario. The developed model can identify the optimal location where the LiFi, WiFi and LTE can be installed so that the overall capital and operational expenditures of the communication platform can be minimised. The problem is solved subject to the requirements imposed by rail-specific applications such as, UHD video streaming, in-cabin surveillance and monitoring, metering applications etc.

Once the topological problem has been solved, its performance in terms of throughput, latency and reliability has been examined using analytical models based on Markov Chain analysis.

Recognising the fact that the proposed communication platform exhibits a large degree of heterogeneity in terms of technologies, a novel management framework combining Software Defined Networking (SDN) and Network Function Virtualisation (NFV) approaches has been considered. This framework offers the ability to create infrastructure slices over the heterogeneous network. Through this approach, railway system operators can instantiate and operate several virtual infrastructures enabling multi-tenancy, supporting jointly energy and telecom services. This allows operational and end-user services (e.g., Communications Based Train Control CBTC, Voice and data between central Command & Control and driver/cabin, streaming of surveillance video inside train and along railway infrastructure, monitoring of infrastructure devices, fleet management etc.,) currently provided through multiple technology-specific communication networks to be multiplexed over common infrastructures providing significant benefits in terms of cost and energy efficiency. A typical example of an SDN /NFV architectural framework adopted in IN2DREAMS is illustrated in Figure 3.

FIGURE 3 — a) Example of an SDN/NFV-based control and management framework for Heterogeneous Network and Compute Infrastructures, b) Service chaining over heterogeneous network infrastructures supporting IoT services 1) IoT data stream over C-RAN, 2) IoT data stream over LTE, 3) IoT data stream over LiFi/WiFi

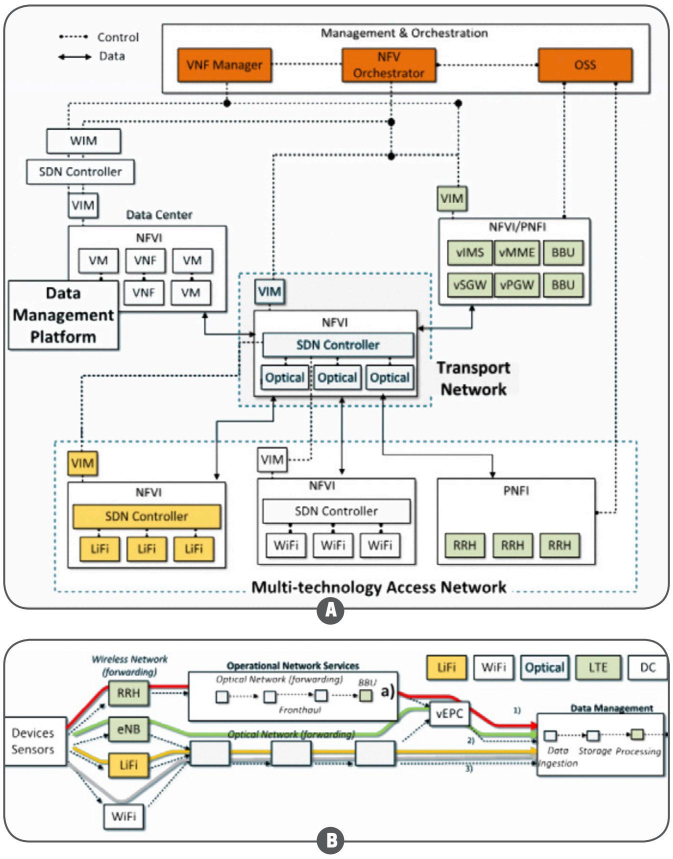
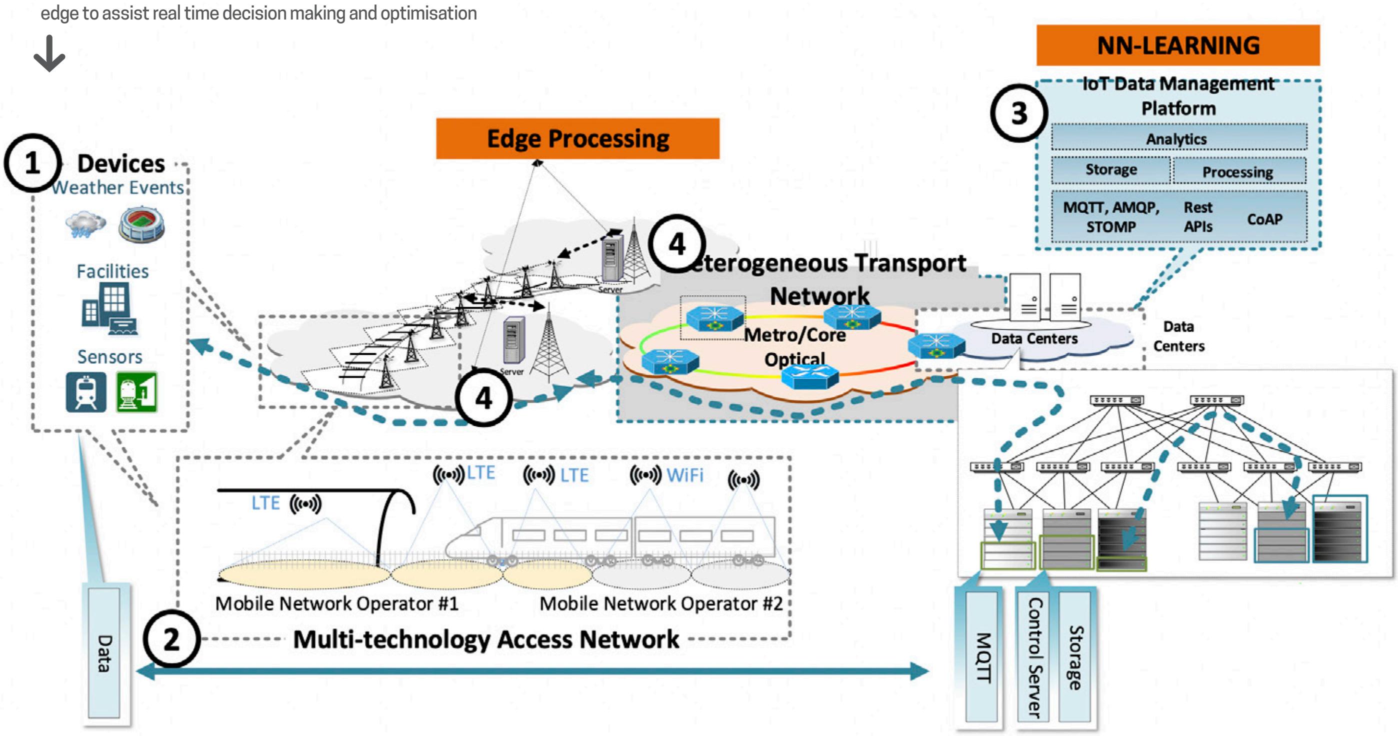


FIGURE 4 — Collaborative Central Cloud/ Edge cloud processing in IN2DREAMS: 1) Data Collected from sensing devices (2) are transmitted over a multi-technology network (3) to the cloud-based data management platform where training of the NN is performed (4). The trained NN is forwarded to the edge to assist real time decision making and optimisation



Sensing / Monitoring Devices and Data Management Platform

Another aim of the project was to build a real time monitoring platform able to collect measurements from a variety of sensors and devices and then send these measurements to the railway control centre for further processing and analysis. To achieve this, a Data Management Platform has been deployed operating in accordance to the Mobile Edge Cloud (MEC) computing paradigm. The key idea is that through the placement of servers with moderate storage and processing power close to the edge of the railway system, the need for long-haul connectivity between end-devices installed either on board or at the trackside and central data management platform can be reduced. This approach allows provisioning of a wide set of delay sensitive services including, location tracking, augmented reality content delivery, video analytics, real-time driver's profile optimisation and application-aware performance optimisation.

The MEC-railway assisted architecture adopted by the IN2DREAMS project relies on a collaborative central-cloud and edge processing (EP) solution. The rationale behind the proposed approach is that computationally intensive tasks (i.e. training of a neural network (NN) using a huge volume of history measurements) are offloaded to the central cloud whereas tasks with very low latency requirements are processed at the edge by purposely developed hardware. An overall view of the implemented architecture enabling EP is shown in Figure 4.

According to the scenario shown in Figure 4, data collected from the various sensing devices are transmitted to the central cloud where the ODM platform is hosted. The stored time series is then used to train purposely developed NNs and machine learning algorithms that can perform a plethora of operations and applications including real time monitoring, decision making and optimisation. A description of the optimal NN topology is then uploaded to the document database as an eXtensible Markup Language (XML), YAML or JSON file which can be then accessed by the EP devices. The EP devices in their turn use these topologies to perform real time decision making and optimisation. Update of the NN topologies is performed frequently in order to keep performance of the overall system at the required level.

This solution has been validated over two large scale experimental campaigns carried out at i) Network Rail facilities addressing topics related to infrastructure monitoring over commercial lines and, ii) CAF's operated tramway depot in Zaragoza Spain. To realise this, a new set of non-intrusive dedicated Hardware sensors was installed and a gateway responsible to record the position of the devices (GPS) and monitor kinematic (accelerometers, gyroscopes, compass, Vibration), energy related and environmental parameters (Temperature and luminosity).

The use cases that have been implemented adopting the proposed collaborative central cloud - EP approach include:

- Forecasting of energy, environmental and kinematic parameters using Long Short-Term Memory (LSTM) and Multi-Layer Perceptron (MLP) NNs;
- Clustering of driving styles to improve the energy efficiency of railway systems;
- Estimation of on-board from trackside measurements to alleviate the need for expensive hardware;
- Fault detection using autoencoders (AE).

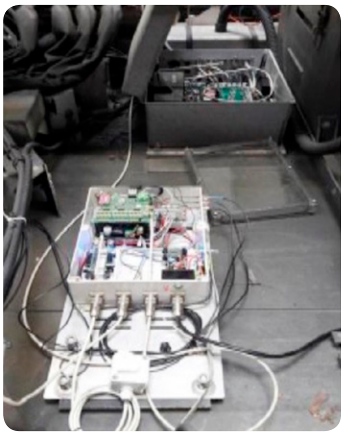


FIGURE 5 — Installation of the acquisition box Aloha V1 on tram's roof

User Applications

In order to develop a data analytics platform to assist railway operators and managers, an efficient IT infrastructure is needed to develop specific applications. The QMiner software was selected as infrastructure basis for the platform as it can achieve a high level of flexibility and scalability.

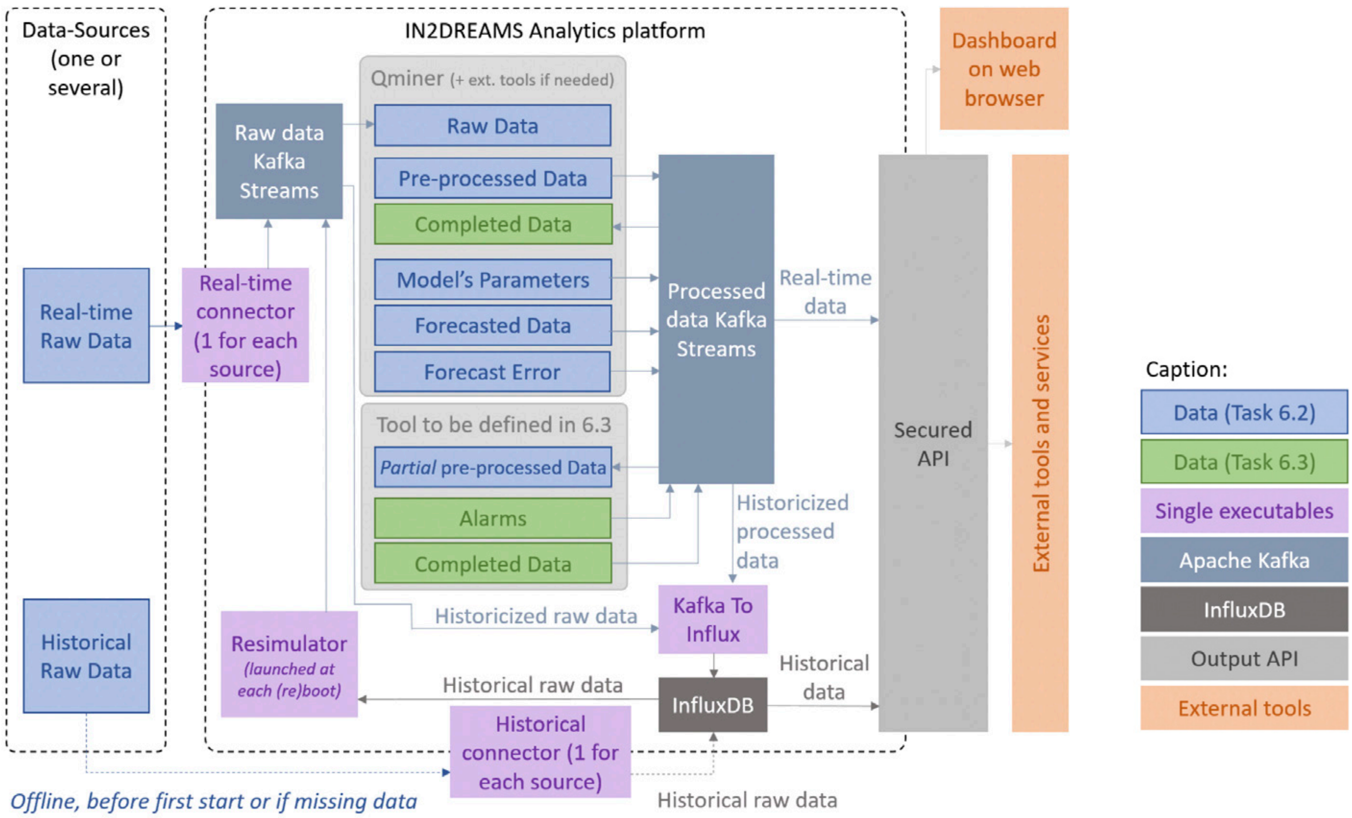
The next objective was to design and develop data analytics solutions for predicting energy demand on railways infrastructure. These solutions are the basics for developing use cases in the field of energy management and asset management, keeping in mind that the final objective is to assist infrastructure managers and railway operators to select optimal strategies and resources in a cost-effective and energy-efficient manner for railway applications.

The next figure is showing the detailed architecture of the analytics platform. Based on its implementation, further analytics algorithms and application have been designed and developed supporting the use cases development in the field of energy management and asset management.

Initial design of solutions followed two main analytical use case implementations, namely: "LIGHT" node for on-board energy data forecasting for extremely short-term forecasting and "FULL" node, for substation data forecasting for longer time horizons.

Test of models developed yield various levels of accuracy, based on different prediction horizon selected. The results offer important insights into further applications in energy and assets optimisation solutions modelling and development. The project results also offer important insights into some of the challenges faced when developing energy data analytics solutions and limitations (mainly energy forecasting).

FIGURE 6 — Detailed data flow with input and output



Furthermore, because it is sometimes difficult or impossible to acquire all of the real data of a whole train line, the simulation of the data (especially energy data) could be very helpful for the analysis of railways infrastructure. The results are based on the Reims tramway use case coming from the In2Rail project and from a train line coming from Network Rail of the In2Stempo project. Both train lines were partially instrumented (1 out of 7 substations and 2 of the trains for the Reims line, for example). Therefore, if the data collected is representative of the data of the whole line and if the results of the simulations are compatible with the measured data, this would indicate that it might not be necessary to measure all energy and dynamic parameters of each train on the whole line. Instead, measuring only the dynamics of the trains and simulating the consumption data could be representative of the train line and sufficient to apply forecasting models for energy consumption.

Data was simulated using the SIGNON software. By comparison with the real data, the simulated data was validated. This shows that it is possible to simulate power system data and to estimate energy consumptions with sufficient precision to then feed them into forecasting models.

Moreover, fault detection techniques were tested and validated, proving that it is possible to detect abnormal voltage activity on different voltage operation lines. This will help to increase performance of railways infrastructure.

Hence, this work opens new development possibilities. For example, the simulated data and the correction of fault detection can be used to enrich real datasets in order to increase the performances of the energy forecasting models.

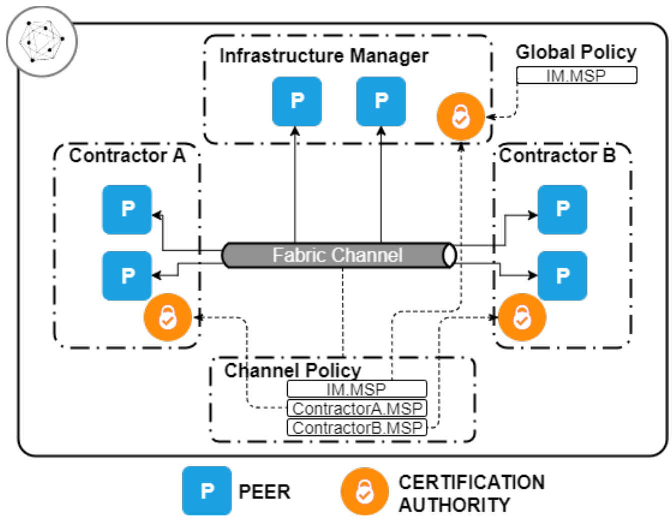
Smart contracts for Railway Data Transactions

The main goal of the Smart Contracts for the Railway Ecosystem was to provide novel distributed ledger technologies (DLT) and smart contracts (SC) framework for Railway Data Transactions Exchange in the context of Asset Maintenance and Infrastructure Managers (IM). The most relevant contribution was to identify the scenarios for applying the DLT and for one specific selected scenario, to develop a Proof of Concept.

To reach the objective, the work was organised into the following four tasks:

1. Definition of data exchange scenarios;
2. Smart contracts solutions for data transactions;
3. Development and Testing;
4. Legal aspects of information and data exchange.

FIGURE 7 — IM Reference Architecture for the PoC



During the first year, four main scenarios have been identified (Asset Maintenance. Procurement, Train Path Allocation and Data Marketplace). A scenario was then selected, related to asset maintenance, which was studied in detail (processes, actors, needs) and then implemented in a PoC with the following vision: “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”.

A complete set of use cases considering all the actors in the IM ecosystem have been considered for the PoC.

The results are summarised below:

- Study and definition of the Use Cases and Requirements;
- Definition of the Data Transaction model in railways ecosystem (not public);
- Definition and study of legal aspects for applying smart contracts to transport ecosystem;
- Development and testing of an end-to-end PoC for Smart Contracts (Technical Demonstrator, see Figure 8 showing a screenshot).

FIGURE 8
The interface of the PoC with the entities involved: assets, transactions and participants

The benefits that have been demonstrated are linked to the ability of removing a single centralised third party for authorising transactional exchange of information and the ability to automate self-executing logic. The study has also revealed that this approach now needs to be tested in a real environment. In the future, DLT and SC may play a relevant role in developing solutions to transform the railway ecosystem and to develop a new generation of services, especially when combined with artificial intelligence. In particular, the IM is the typical complex ecosystem, where there are plenty of actors and there are potential applications of DLI and SC for simplification, digitalisation and sustainability.

Knowledge extraction from Railway Asset Data

Another goal of the IN2DREAMS project was to study, design and develop data analytics solutions for knowledge extraction from railway asset data. The most relevant contribution was to identify the scenarios for applying the DLT and for one specific selected scenario, to develop a Proof of Concept. This objective has been achieved through the following tasks:

- Definition of data analytics scenarios;
- Development and demonstration of tools and methodologies aiming at extracting knowledge from data analytics algorithms, contemporarily making them interpretable in an easier way;
- Study and proof-of-concept of metrics and methods/tools to measure the accuracy of analytics algorithms.

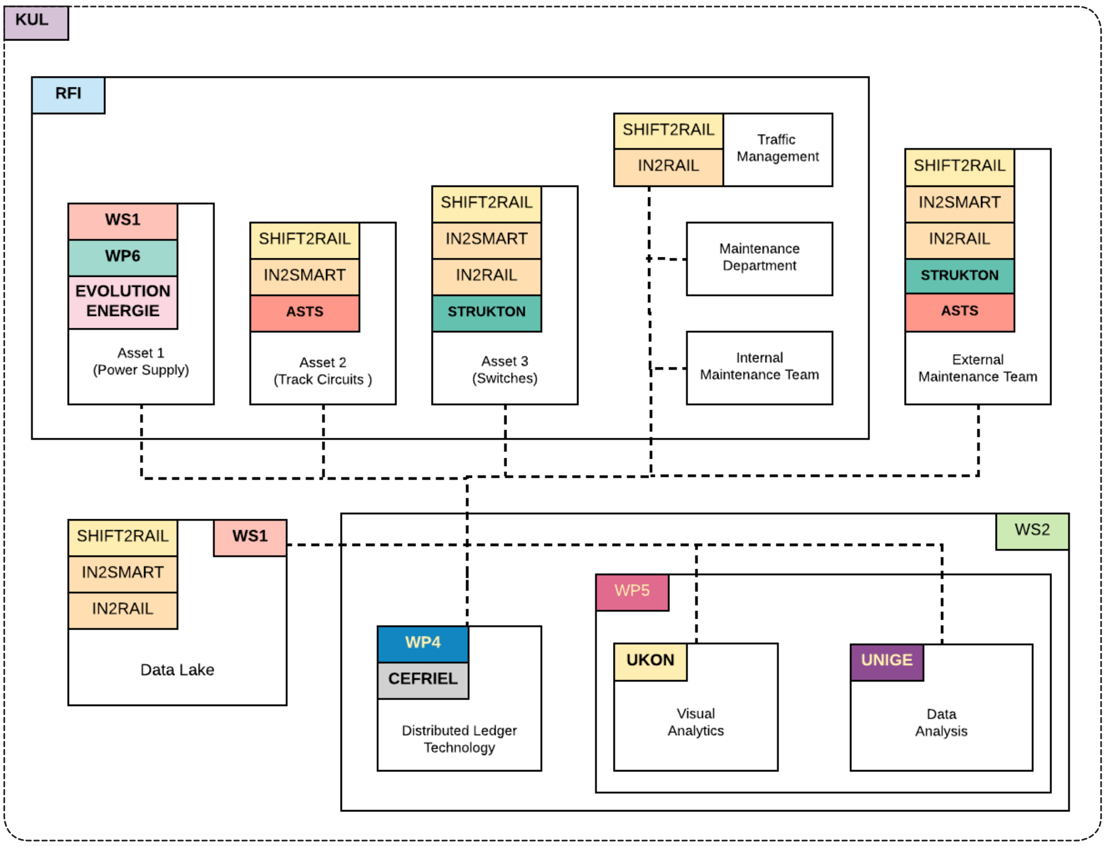
Seven scenarios have been developed (see Figure 9). Two of them are cross-scenario in the sense that they cover, in some way, many aspects of the railway ecosystem while five of them are specific-scenarios in the sense that they focus on a single particular aspect. The two cross scenarios are:

- Cross-Scenario 1 (CS1): Visualisations in Control Center;
- Cross-Scenario 2 (CS2): Marketplace of Data and Data Monetisation.

The five specific scenarios are:

- Specific-Scenario 1 (SS1): Track Circuits;
- Specific-Scenario 2 (SS2): Train Delays and Penalties;
- Specific-Scenario 3 (SS3): Restoration Time;
- Specific-Scenario 4 (SS4): Switches;
- Specific-Scenario 5 (SS5): Train Energy Consumption.

FIGURE 9
The big Picture



Five of these scenarios have been implemented (CS1, SS1, SS2, SS3, SS5) while the others have not been implemented due to lack of data or resources availability.

SS3 has been selected as the subject of the final proof of concept (see Figure 10) since it allows to connect the two WPs (WP4 and WP5) of the WS2. In particular, the demonstrators that have been developed for the scenario on Restoration Time which exploits three modules (see Figure 11):

- the proof-of-concept developed in WP4 for handling the maintenance process as reliable data source thanks to the Distributed Ledger Technologies;
- the data analytics models developed in WP5 for SS3 for predicting the restoration time from each maintenance as important information to provide to the train operators and the infrastructure managers;
- the visual analytics models developed in WP5 for SS1 for displaying the information to the operators coming both from the Distributed Ledger Technologies and the data analytics models.

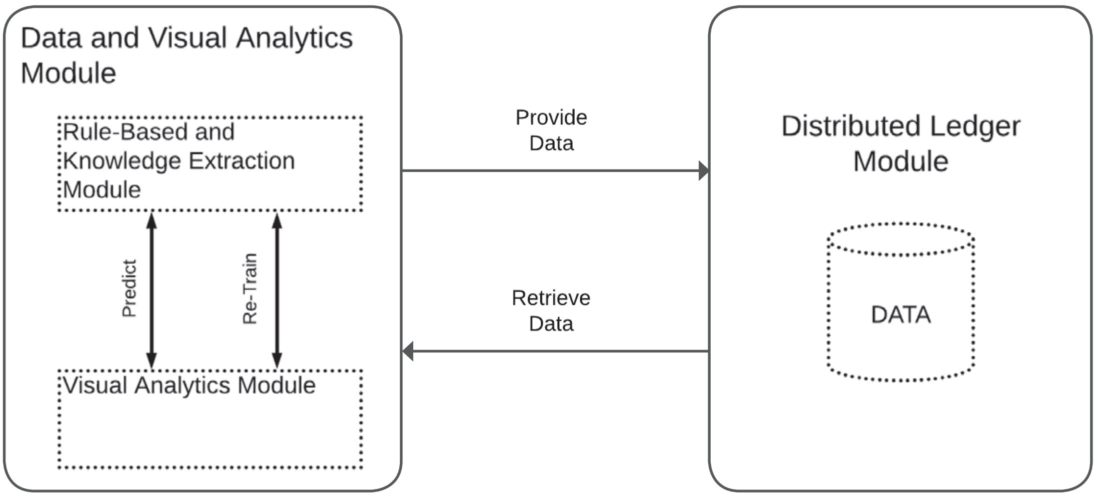


FIGURE 10
Architecture of the proof-of-concept

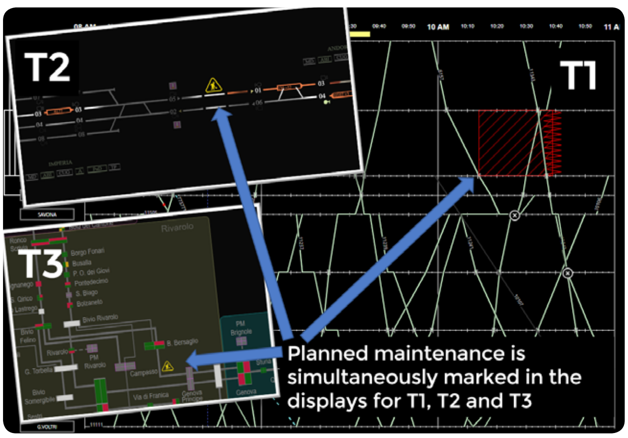


FIGURE 11a
Proof-of-concept demo

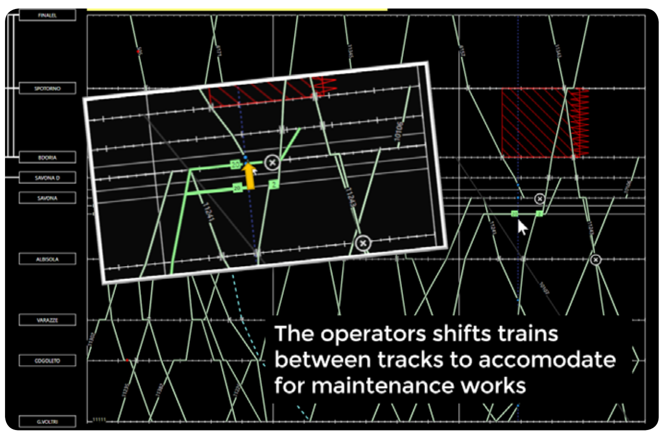


FIGURE 11b
Proof-of-concept demo

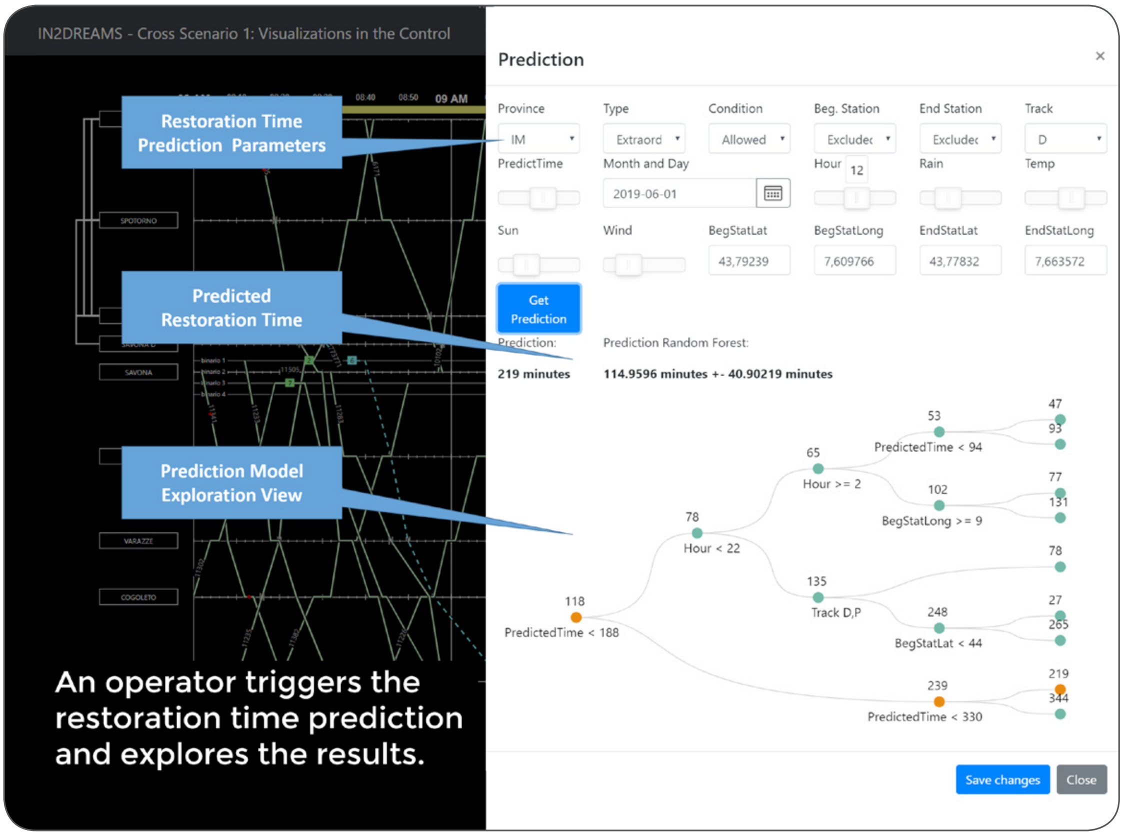
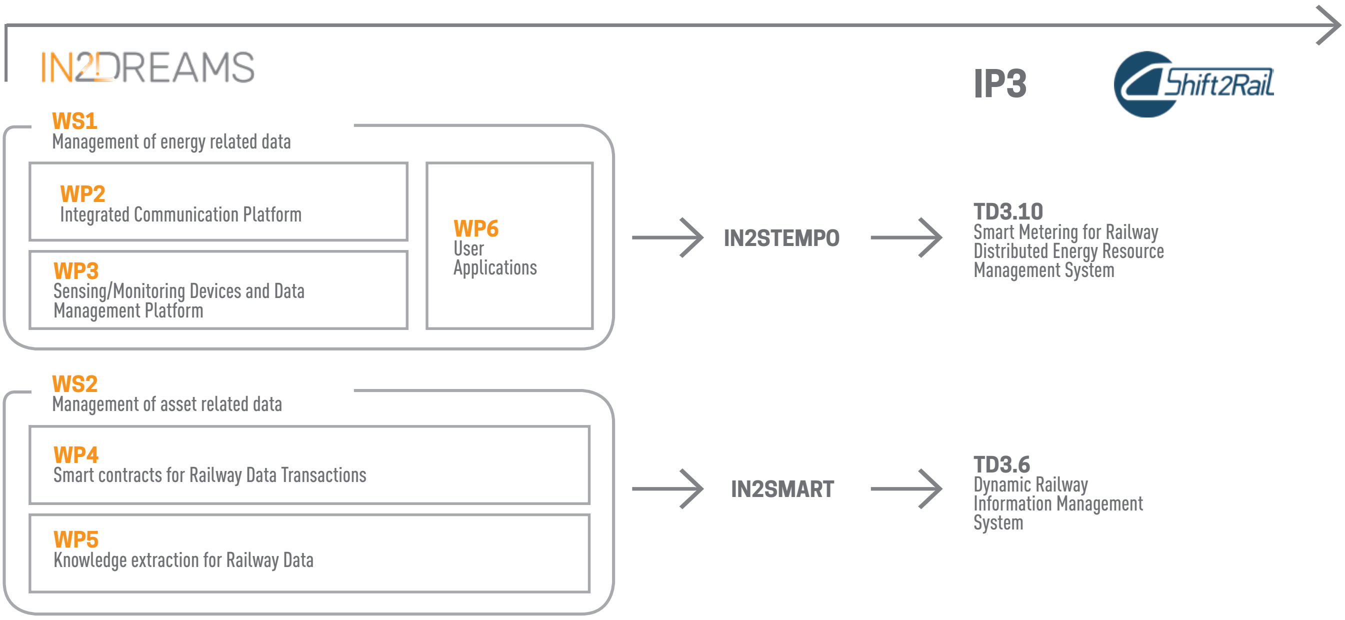


FIGURE 11c
Proof-of-concept demo

IN2DREAMS interaction with Shift2Rail

As depicted in the diagram below, the two Works Streams of IN2DREAMS are closely linked with two other IP3 projects, In2Stempo and IN2SMART. In this respect the necessary collaboration has been established during the duration of the project and will continue where possible even after the conclusion of the project, in order to support the In2Stempo consortium whose work carry on the IN2DREAMS developments.

FIGURE 12
IN2DREAMS interaction with S2R



FACTS & FIGURES

Total Budget
2.2M

Duration
26 Months

Partners
14

Start Date
01/09
2017

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This project has received funding from the European Union`s Horizon 2020 research and innovation programme under grant agreement No: 777596. This document reflects only the author's view and the S2R JU is not responsible for any use that may be made of the information it contains.