5G and edge computing in railways: applications and challenges (IN2DREAMS project)

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5G and edge computing in railways: applications and challenges (IN2DREAMS project)

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Content Outline

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  - Project partners
  - Challenge & Scope
  - High-level objectives
  - Project structure
  - Links with S2R

- **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)
- **Vertical use case: Railway systems**
  - Current status
  - 5G for railways
  - Use case: Smart metering for railway systems over 5G Networks
- **Conclusions**

ICT FOR RAILWAYS

Project Partners

PROJECT COORDINATOR

unife
THE EUROPEAN RAIL INDUSTRY

TECHNICAL LEADERS

DaVinci

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

Challenge & Scope

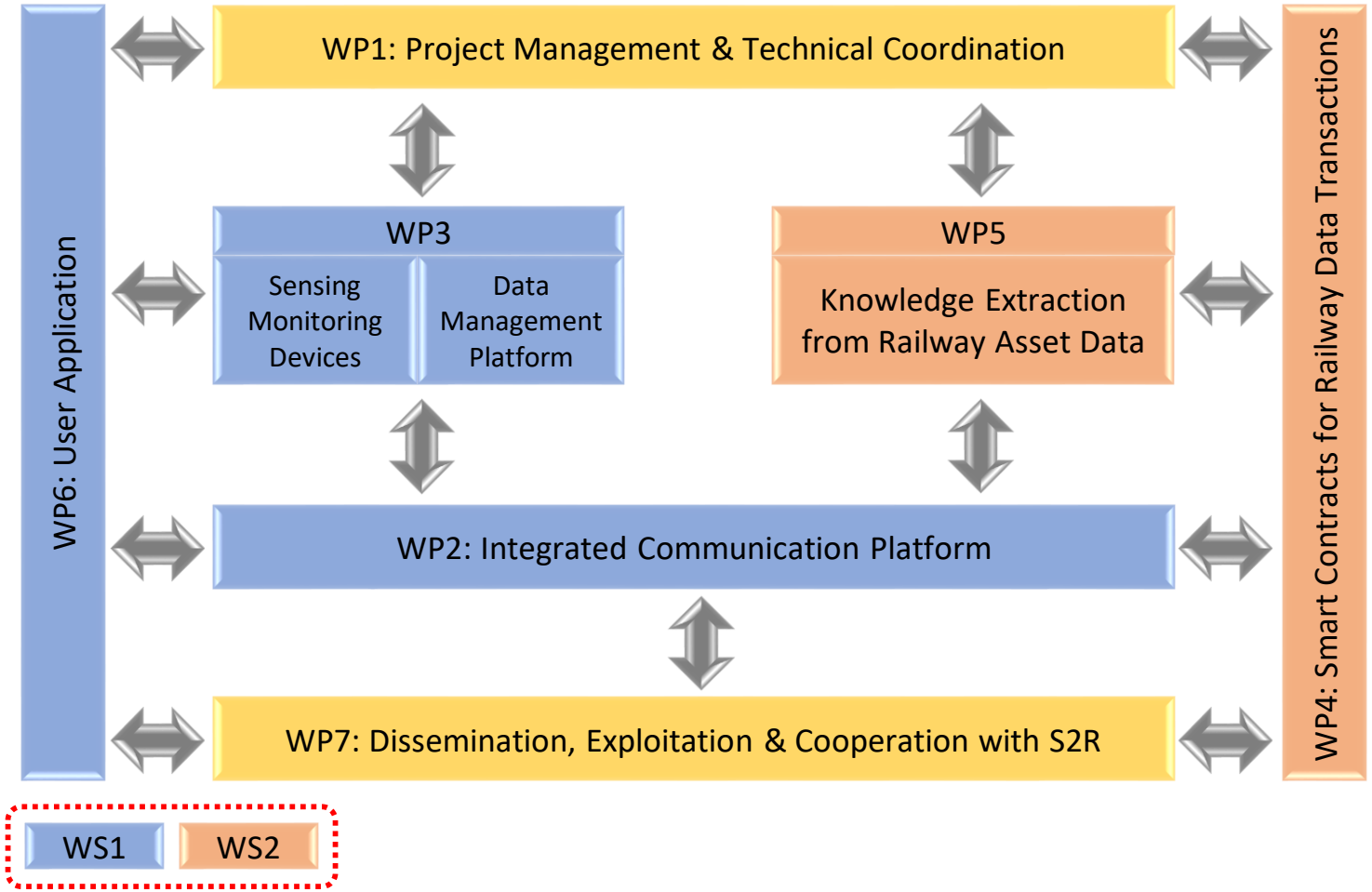
- Predicted growth of transport, especially in European railway infrastructures, is expected to introduce a dramatic increase in freight and passenger services by the end of 2050.
- To support sustainable development of these infrastructures, novel data-driven ICT solutions are required.
- These will 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

High-level Objectives

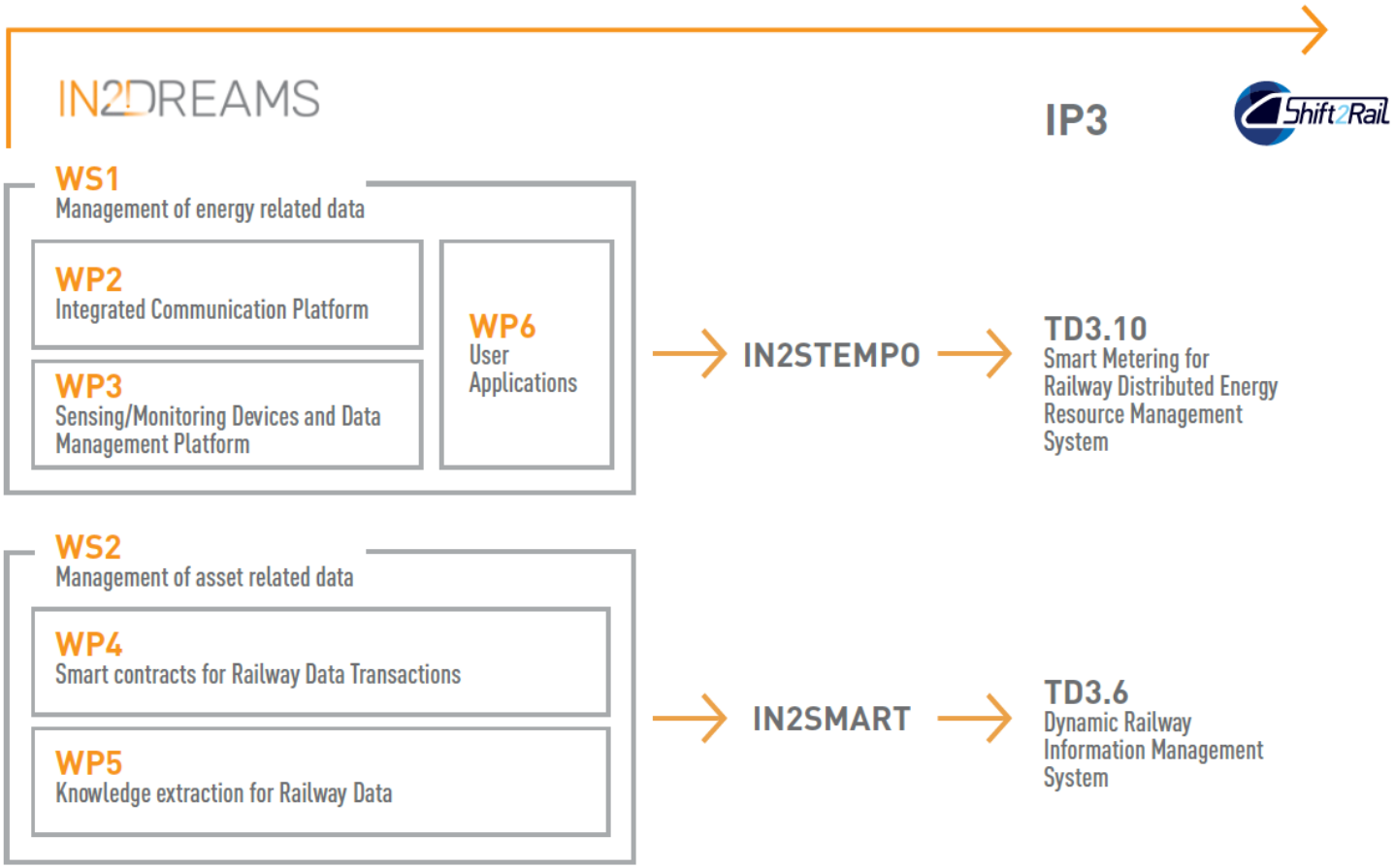
- **Work Stream 1 – Management of Energy-related Data**
- WS1 aimed at removing the current and anticipated limitations of REMS, by making these capable of supporting a much wider array of requirements than it is currently the case.

- **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.

Project Structure



Links with Shift2Rail



ICT FOR RAILWAYS

Join us at the IN2DREAMS final conference!

Where: Milan
When: 2nd October 2019

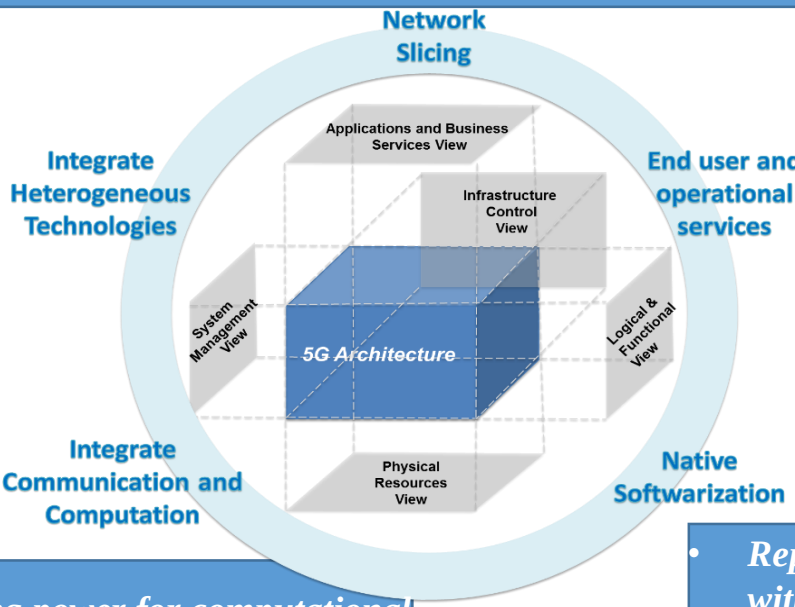
To register keep an eye on our public website:

www.in2dreams.eu

Motivation - 5G Vision

- New business opportunities for a large variety of use cases – ICT & Verticals
- 5G Networks to be future proof: designed to evolve and not to be replaced

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



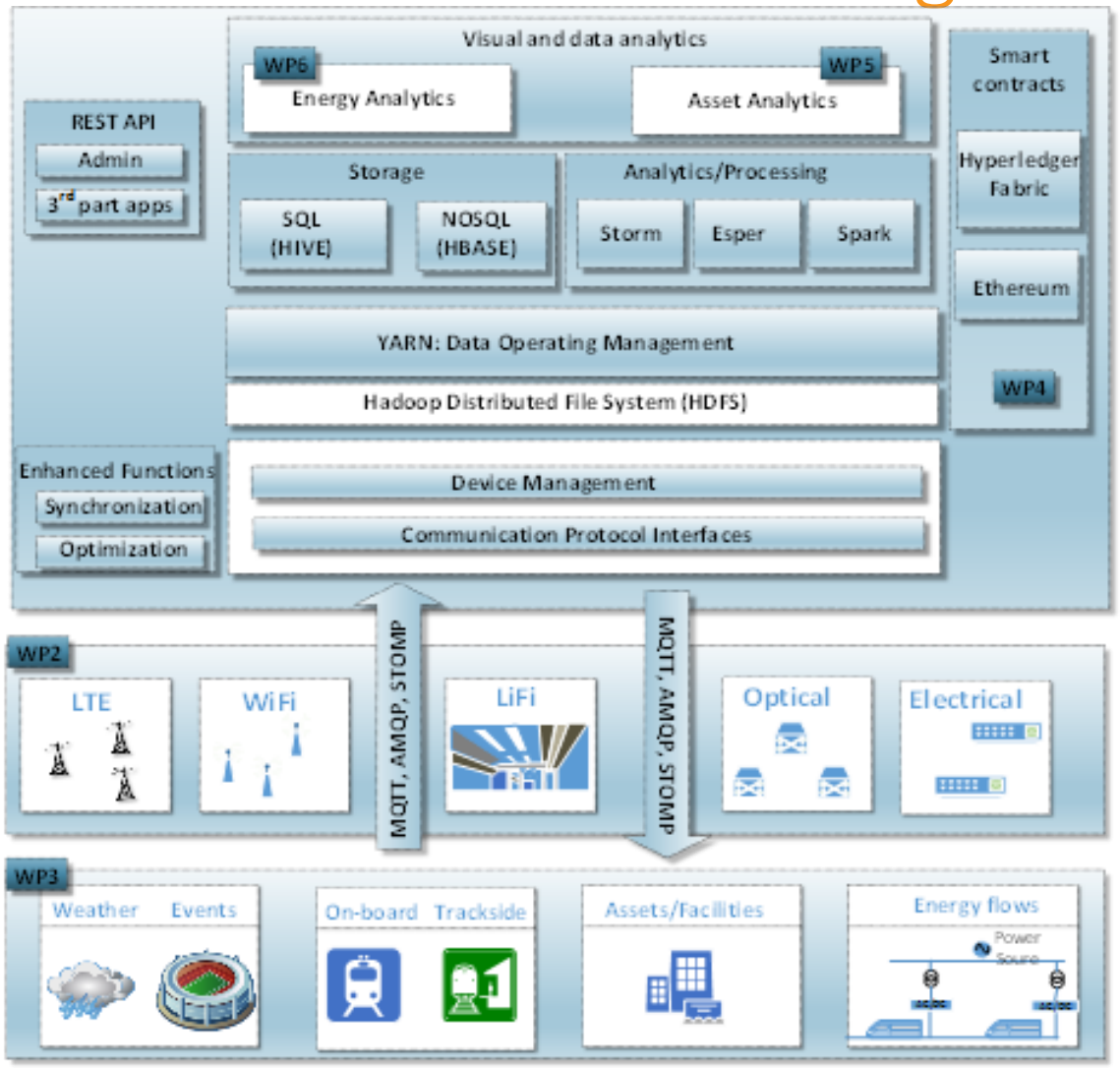
- *Multi-technology networks for access and transport*
- *Improved efficiency, capacity etc*

- *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*

Overall Architecture and Building Blocks

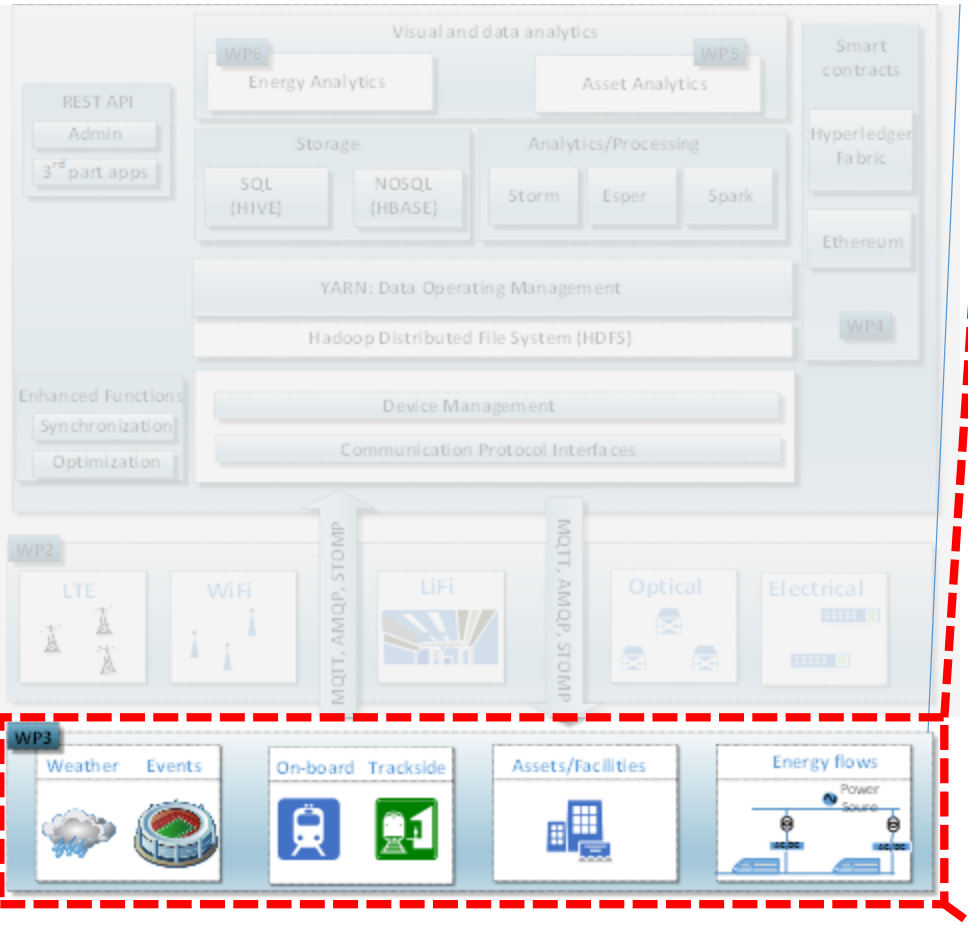


Operational Data Management Platform

Integrated Communication Platform

Sensing/Monitoring Devices

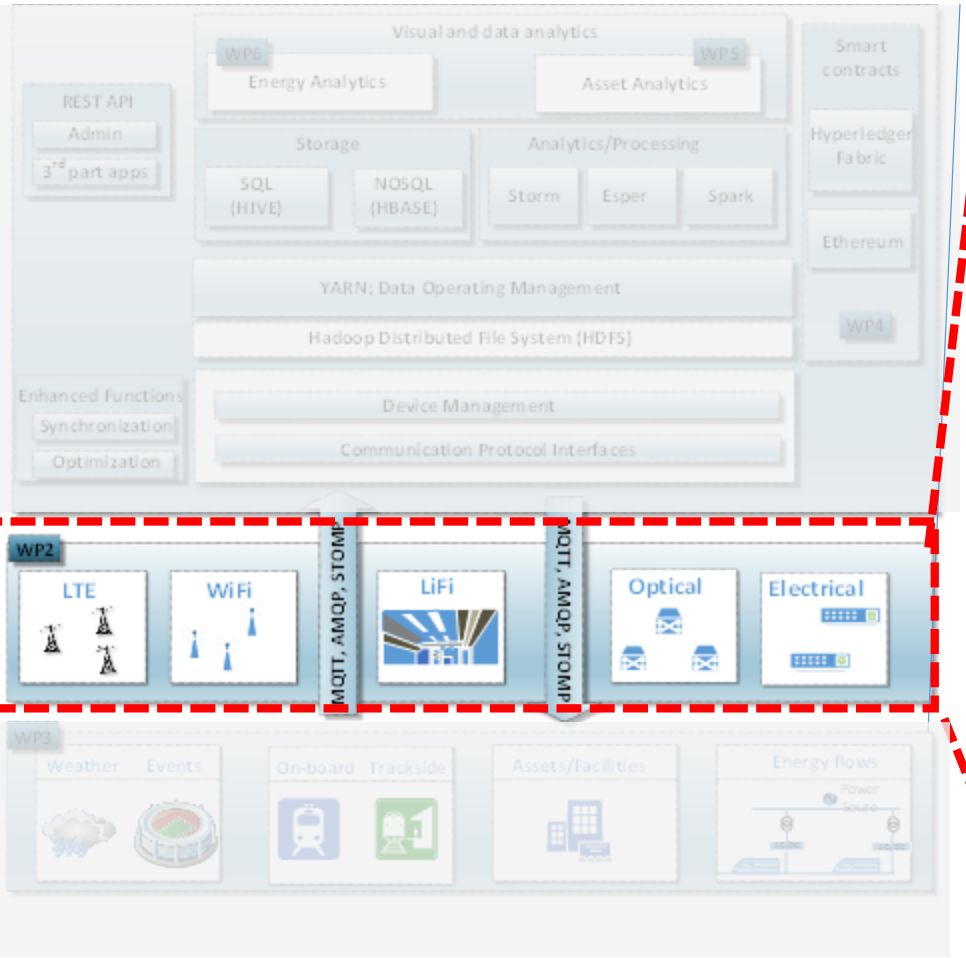
Building blocks (I)



- **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.

12

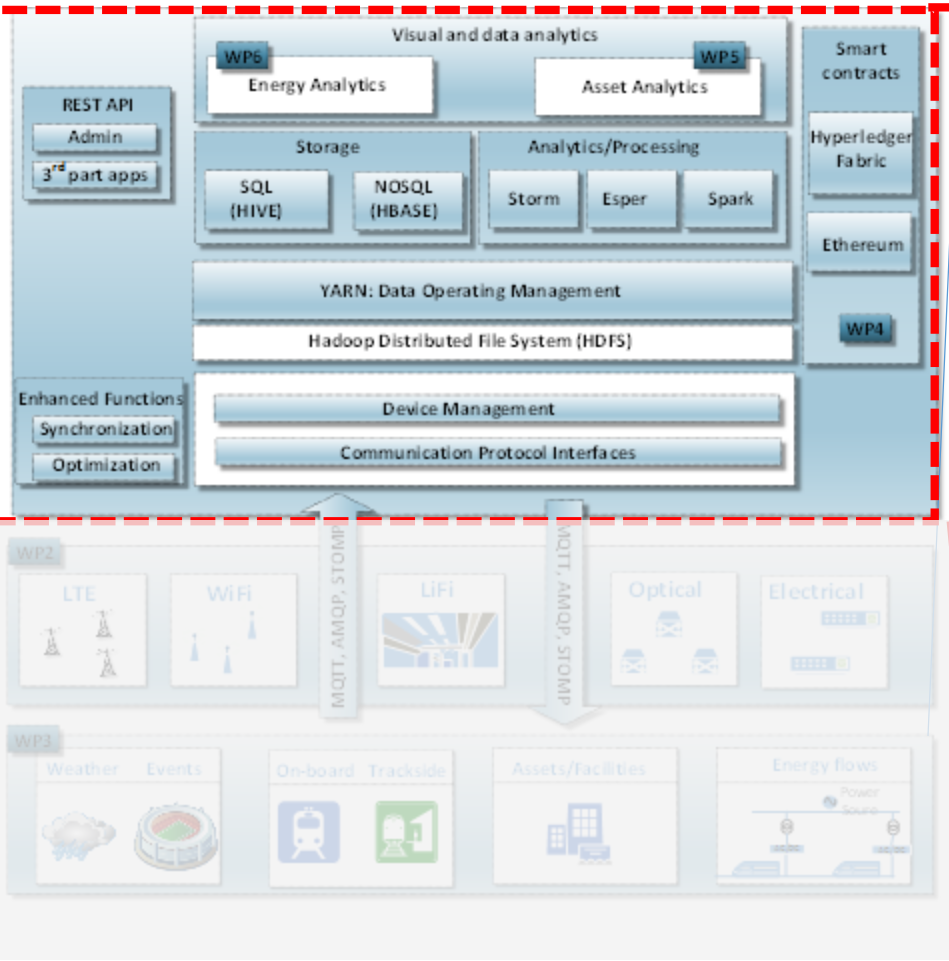
Building blocks (II)



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

Building blocks (III)



ODM Platform

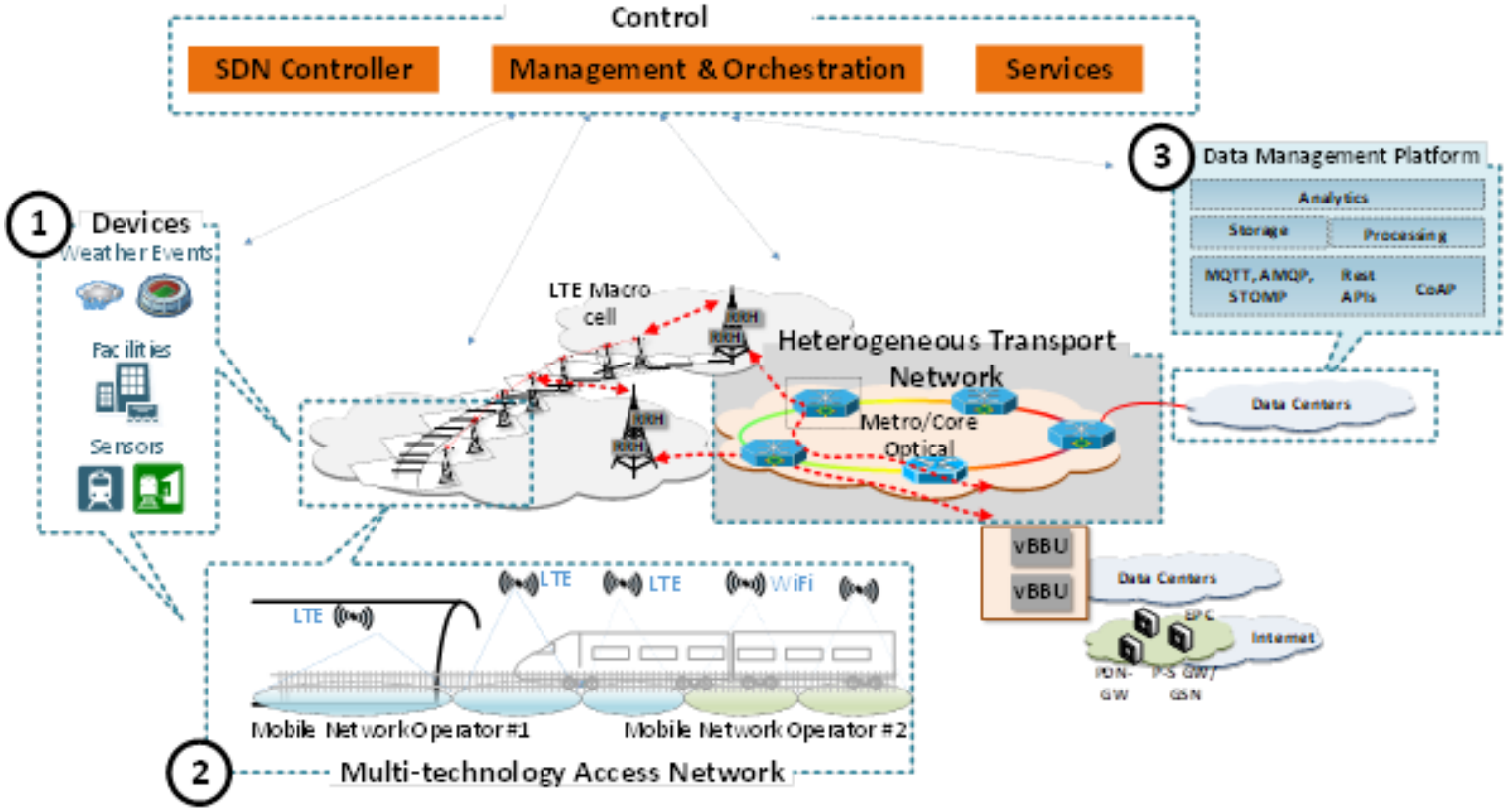
ODM platform offering Scalable Data Collection, Aggregation, Processing and Interfaces offering the following features:

- 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

Communication Networks for railways

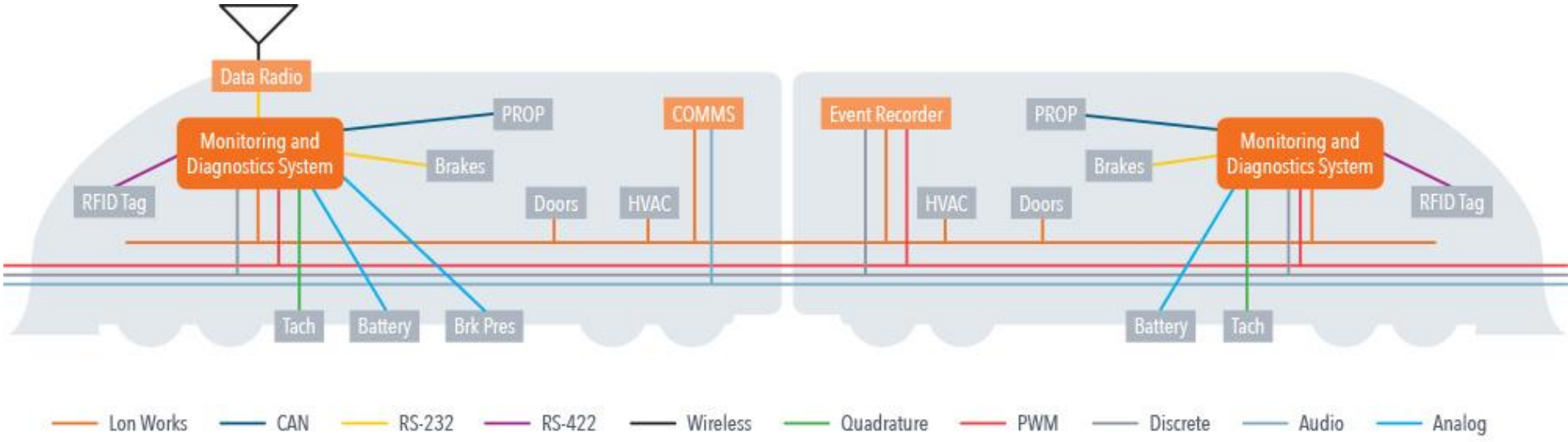
Basic Network Segments of railway systems

- ON_BOARD
- ON_BOARD TO TRACKSIDE
- TRACKSIDE TO OPERATIONS CONTROL CENTER



Railway Communication Systems: Challenges

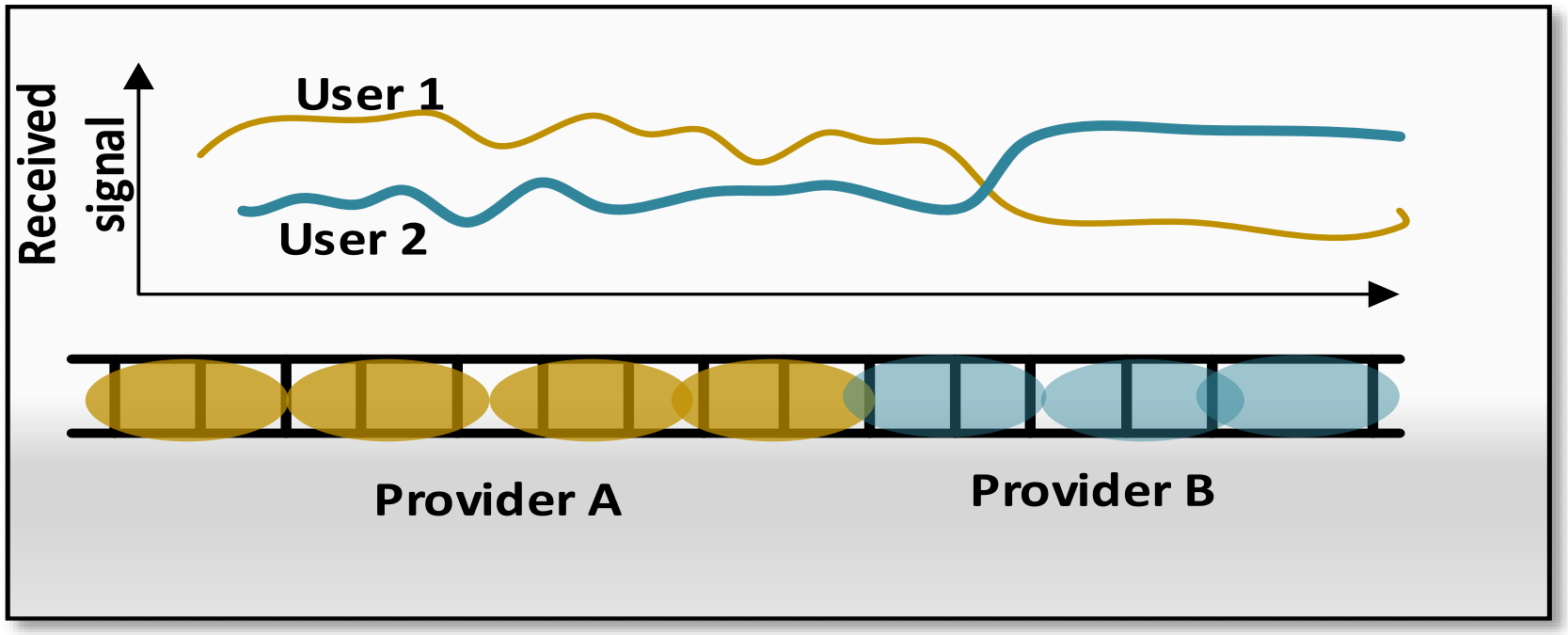
- ***#1 On-board segment: Multiple-application specific networks***
  - Increased Operational/Maintenance costs



Source: http://www.questertangent.com/solutions/train-communication-networks/

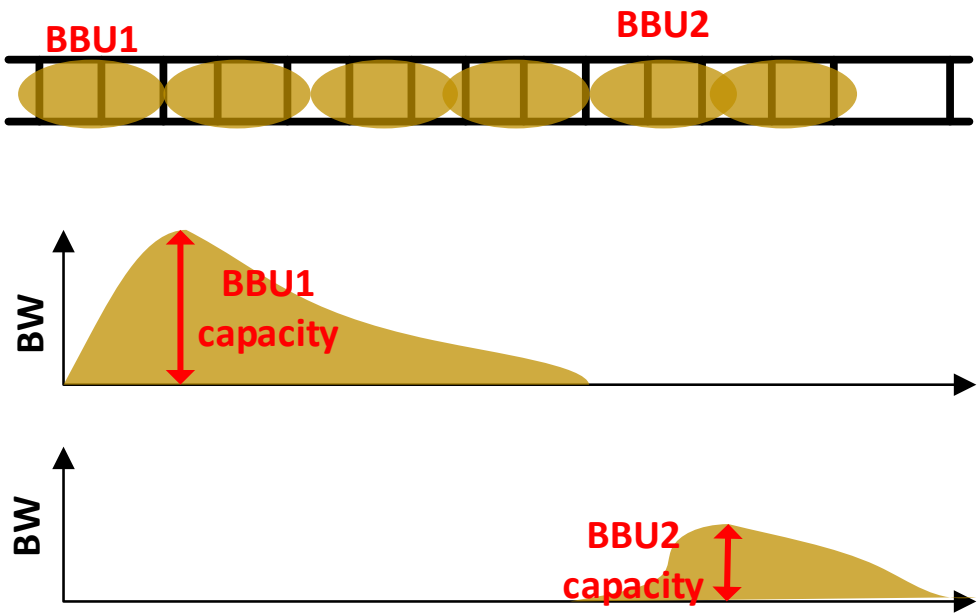
Railway Communication Systems: Challenges

- ***#2 On-board to trackside: based on 3G/4G for passengers and GSM-R for operators***
  - Service disruptions, non-guaranteed QoS across the track
  - Example: User 1 (2) associated with provider 1 (2)
    - Provider A: High SNR, region A. Provider B: High SNR, region B

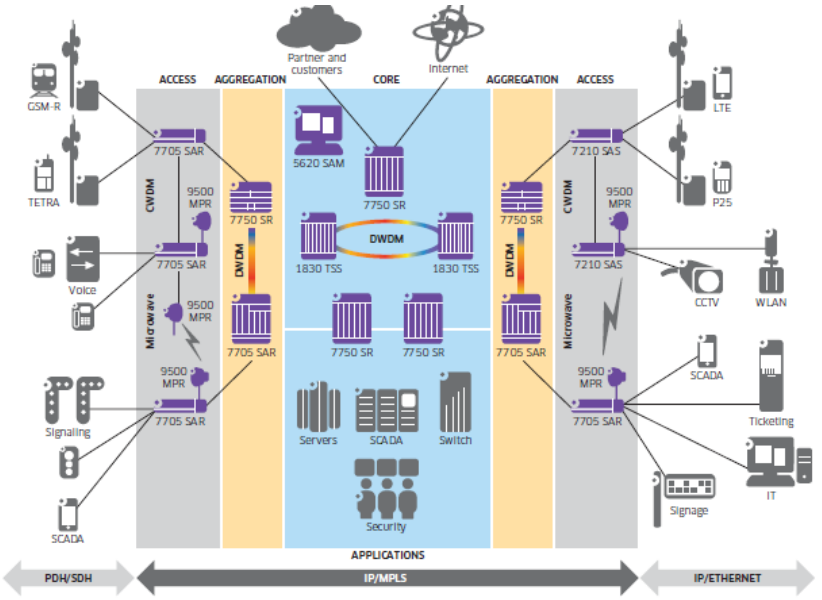


Railway Communication Systems: Challenges

- ***#3 On-board-to-trackside (cont)***
  - Inefficient use of resources i.e., highly underutilized BBU resources, especially in rural environments, low bandwidth (for GSM-R in the order of kbps)



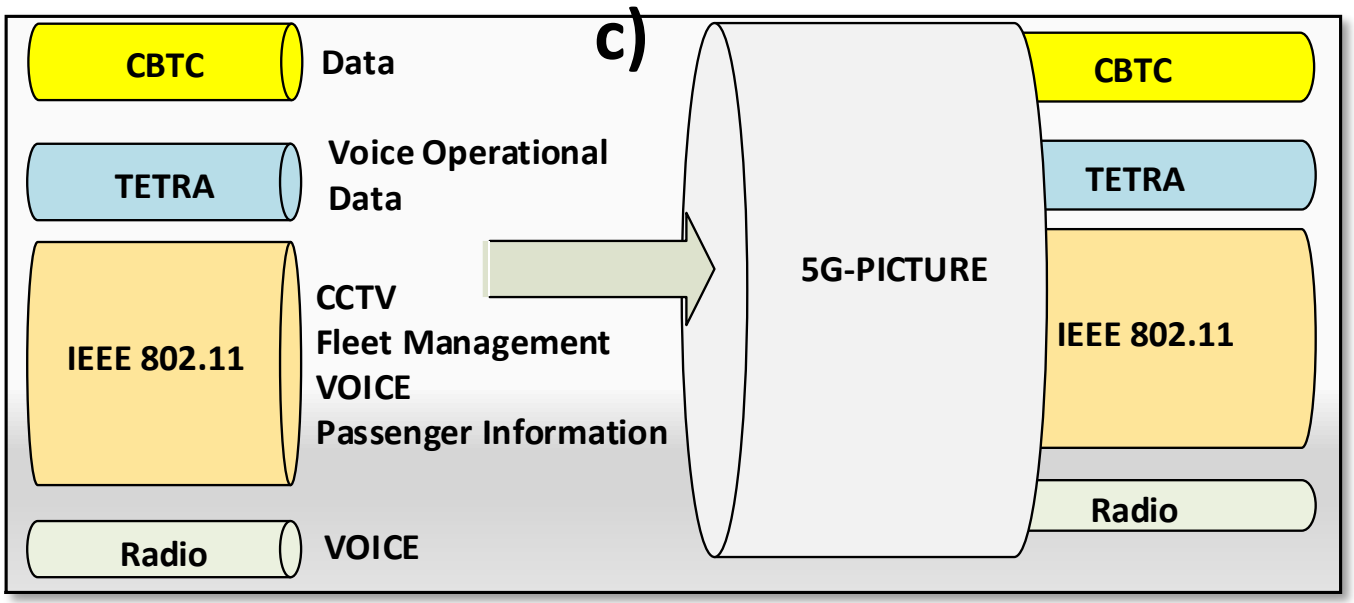
- ***#4 Trackside-to-operations control center***
  - **Vendor Specific i.e.**



https://www.globalrailwayreview.com/whitepaper/27717/mission-critical-communications-networks-railway-operators/

5G-Applications – Sharing of ON_BOARD services

- ***#1:*** Common platform for operational and user services
  - Achieved through infrastructure slicing and virtualization



Field Validation

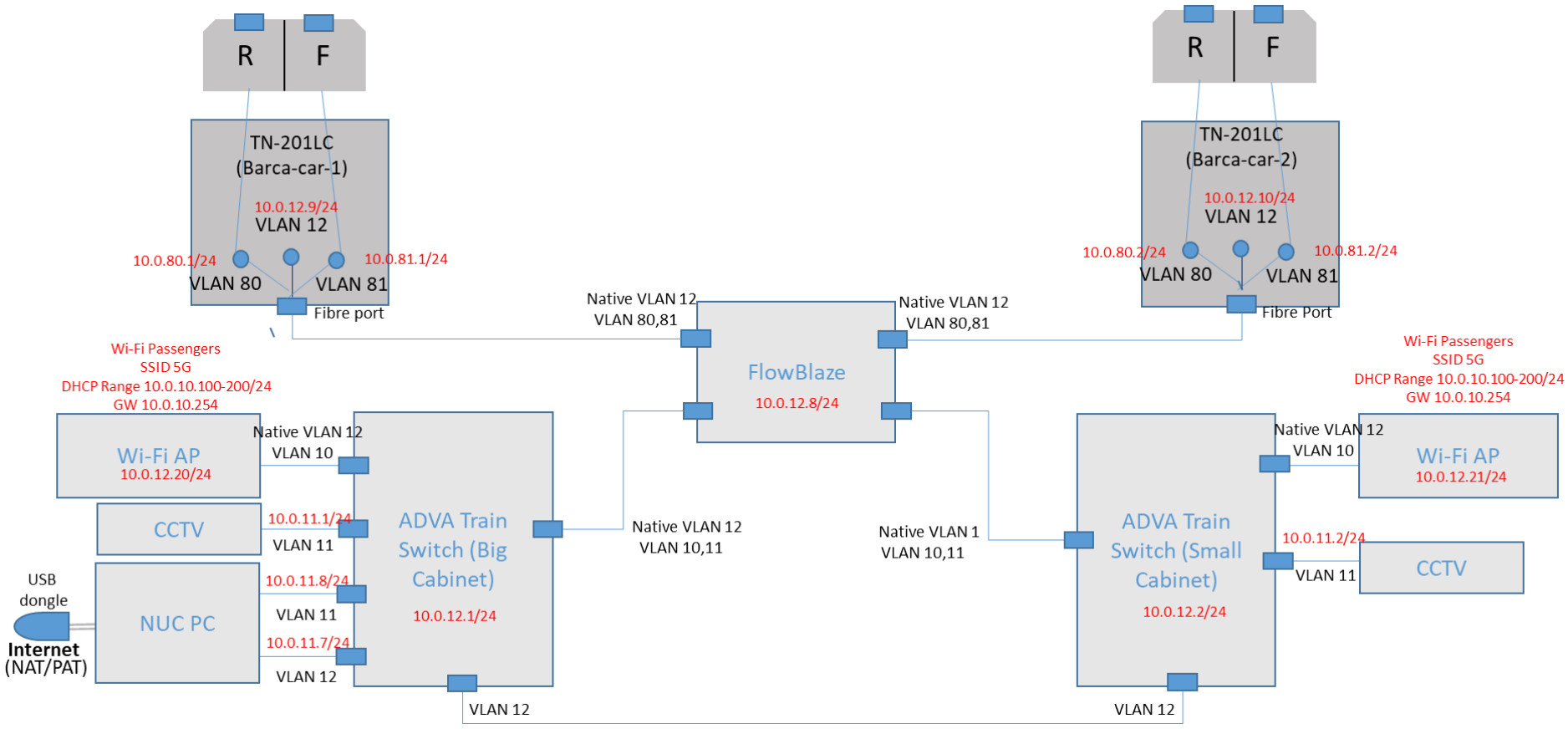
Service Tags:

- VLAN 10: ***Internet Access and file transfers*** (Passengers services)
- VLAN 11: ***CCTV*** (Railway services)
- VLAN 12: ***Management***

Transport Tags:

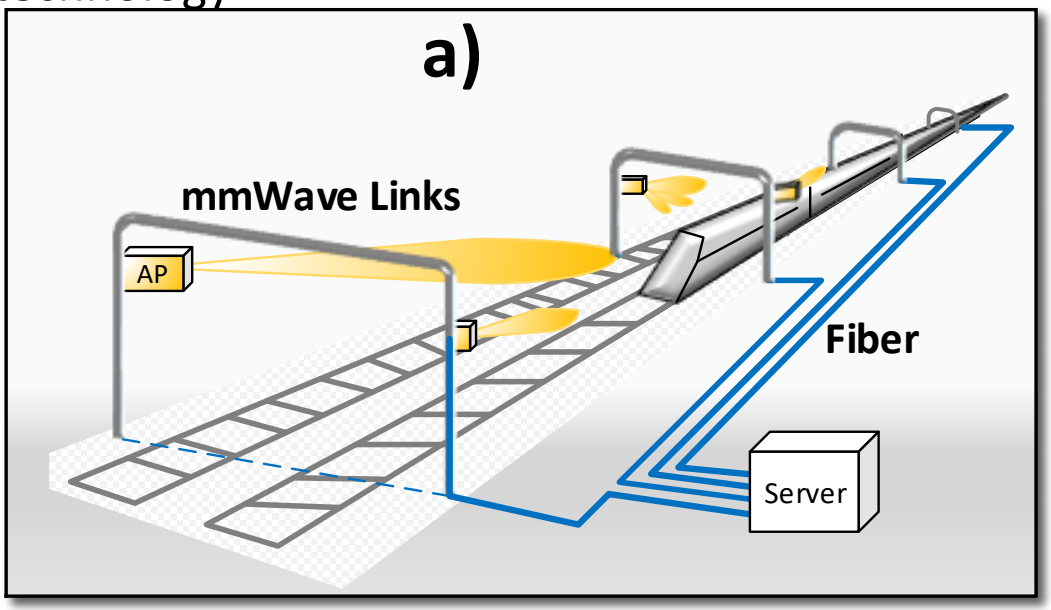
- VLAN 80: **Only on-board**. Between the on-board FlowBlaze and the Rear Antenna of each TN201-LC unit (one VLAN 80 per unit)
- VLAN 81: **Only on-board**. Between the on-board FlowBlaze and the Front Antenna of each TN201-LC unit (one VLAN 81 per unit)
- VLAN 100-107: Between the Martorell FlowBlaze and each of the eight DN101-LC trackside antennas (one per antenna)
- VLAN 1: To avoid loops

Demo (II)


R
F
TN-201LC
(Barca-car-1)
10.0.12.9/24
VLAN 12
10.0.80.1/24
VLAN 80
VLAN 81
10.0.81.1/24
Fibre port
R
F
TN-201LC
(Barca-car-2)
10.0.12.10/24
VLAN 12
10.0.80.2/24
VLAN 80
VLAN 81
10.0.81.2/24
Fibre Port
Native VLAN 12
VLAN 80,81
FlowBlaze
10.0.12.8/24
Native VLAN 12
VLAN 80,81
Wi-Fi Passengers
SSID 5G
DHCP Range 10.0.10.100-200/24
GW 10.0.10.254
Wi-Fi AP
10.0.12.20/24
Native VLAN 12
VLAN 10
CCTV
10.0.11.1/24
VLAN 11
USB
dongle
Internet
(NAT/PAT)
NUC PC
10.0.11.8/24
VLAN 11
10.0.11.7/24
VLAN 12
ADVA Train
Switch (Big
Cabinet)
10.0.12.1/24
VLAN 12
Native VLAN 12
VLAN 10,11
Native VLAN 1
VLAN 10,11
ADVA Train
Switch (Small
Cabinet)
10.0.12.2/24
VLAN 12
Native VLAN 12
VLAN 10
Wi-Fi AP
10.0.12.21/24
10.0.11.2/24
VLAN 11
CCTV
Wi-Fi Passengers
SSID 5G
DHCP Range 10.0.10.100-200/24
GW 10.0.10.254

5G-Applications – ON_BOARD to TRACKSIDE

- ***#2 :*** Integrated multi-technology on-board and trackside network -- of mmwave technology



- Coordination of the remote antennas (RU) adopting the C-RAN paradigm

Field Trial (1)

- **On-board elements, mmWave antennas**

Antenna Module
(on the train roof)

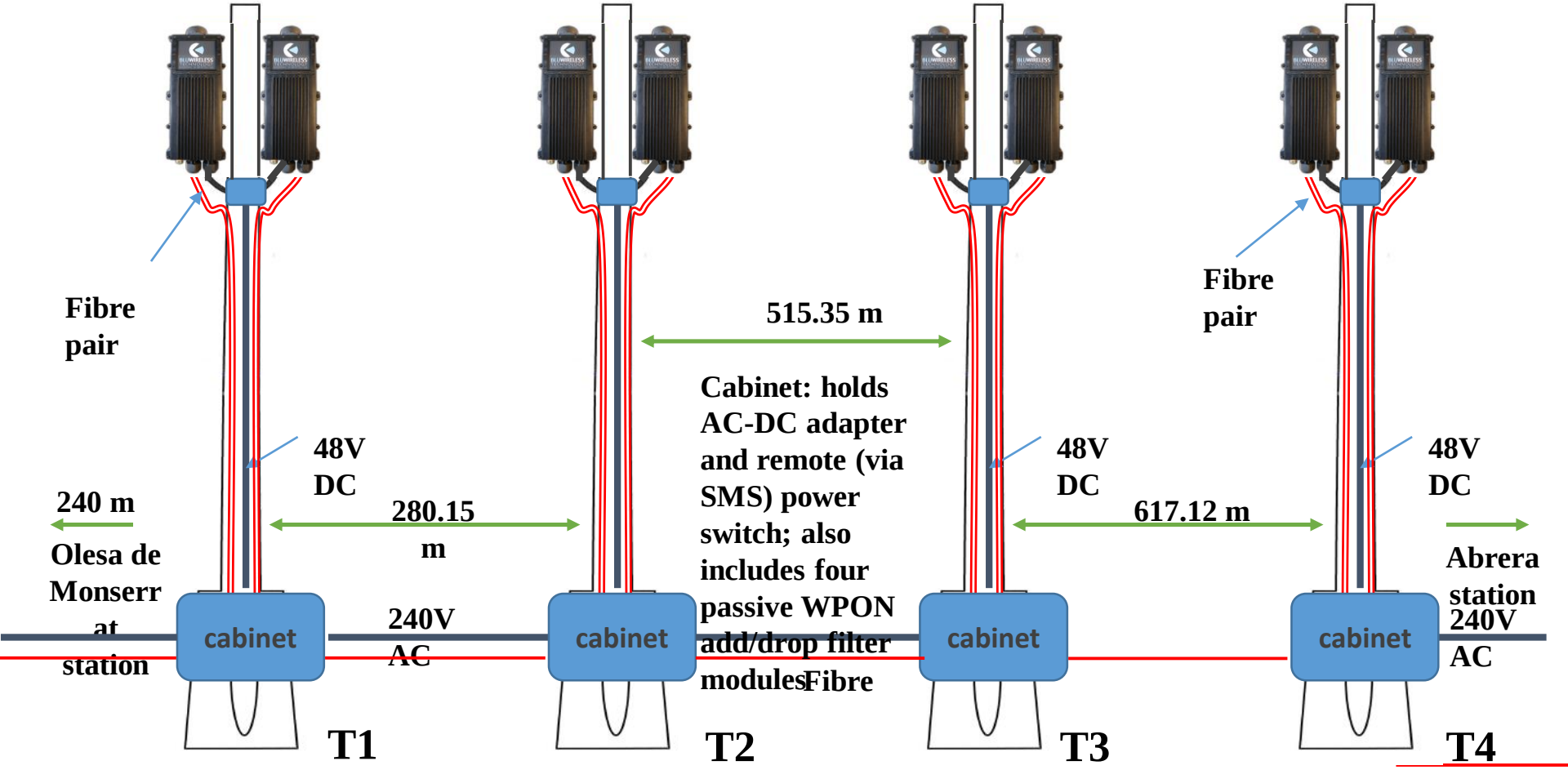
Field Trial (2)

Field Trial (2)

- ***Demo location***

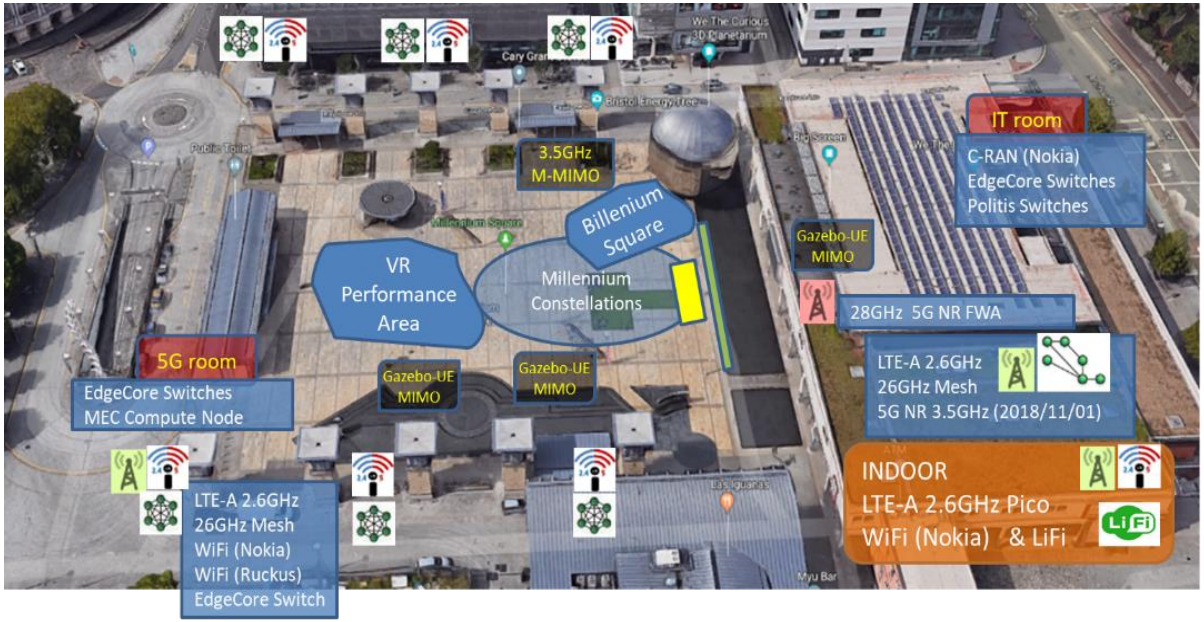
Field Trial (3)

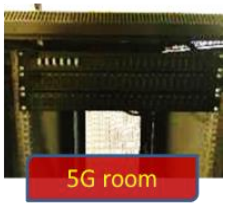
- **Ground elements**

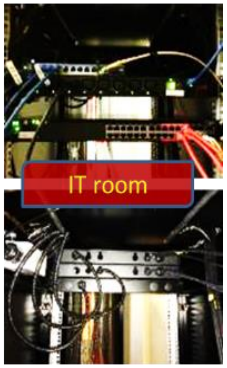


5G-Applications – Multi-technology access and transport

- ***#3:*** *Integrated multi-technology ground infrastructure (Lab validation @Millennium Square Bristol)*

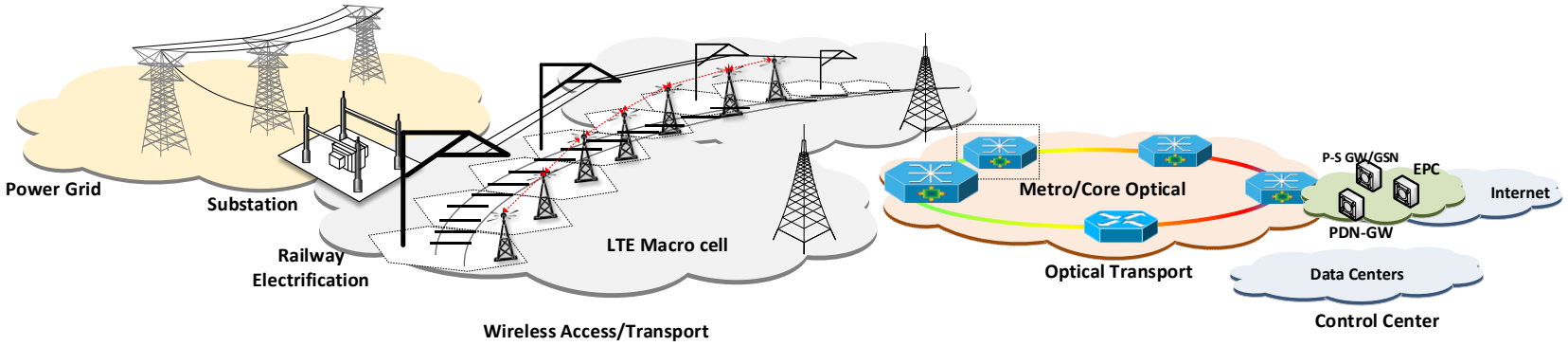






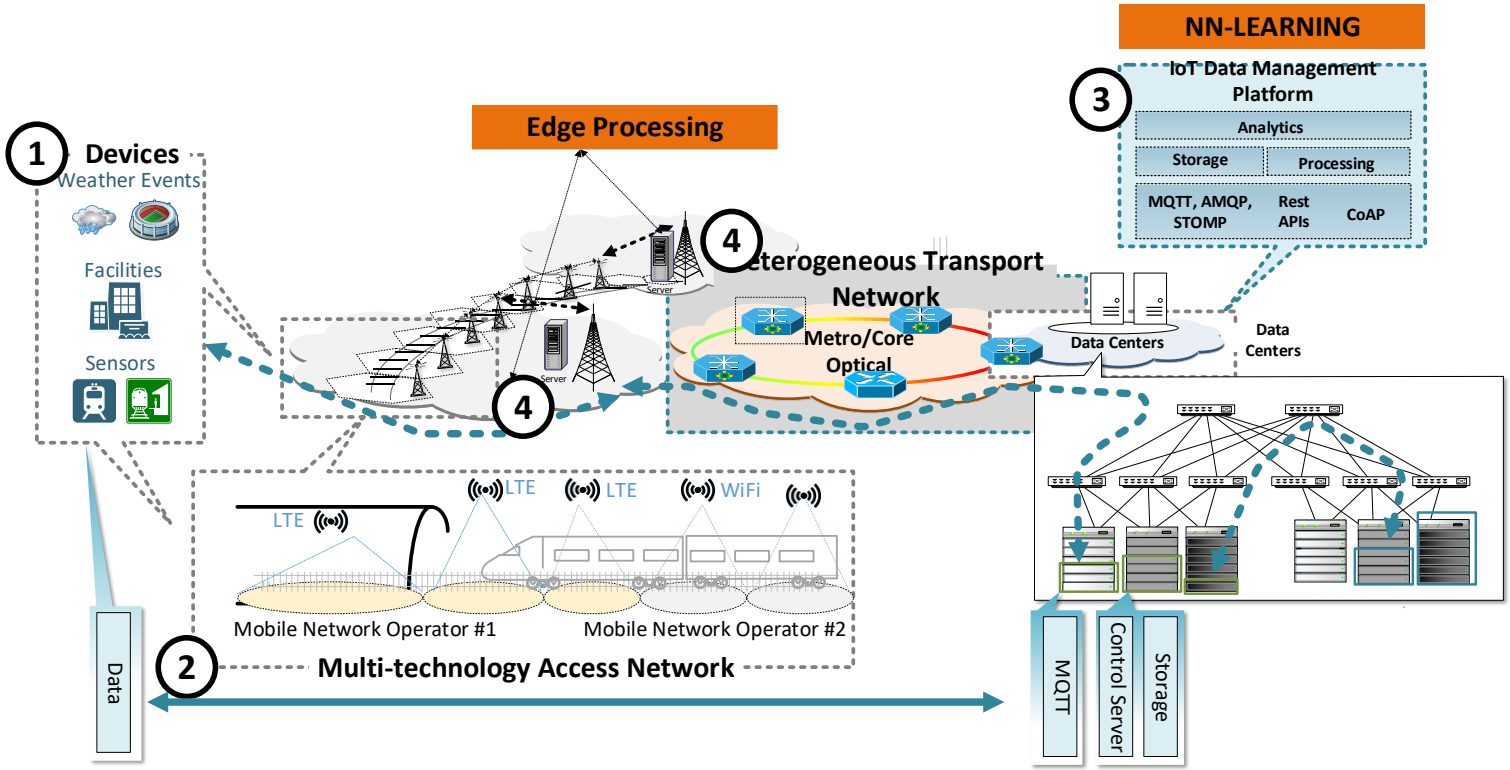
5G-Applications – Softwarization and Optimization

- ***#4 Energy Metering and Optimization***
- Objective: Fast and reliable monitoring, analysis and optimization of the whose railway system including the railway electrification system, the rolling stock and the track.



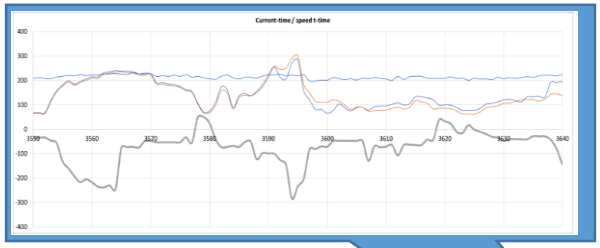
Proposed Solution

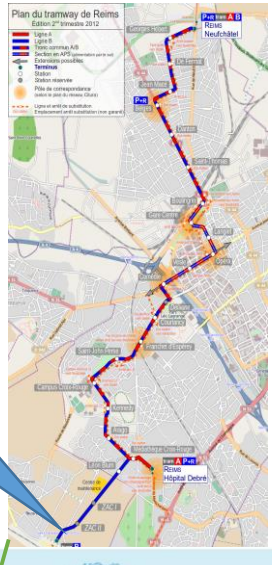
- Adopting the concept of Mobile Edge Cloud (MEC)
- Efficient coordination of disaggregated compute resources
  - Collaborative edge-central cloud data processing → reduced latency

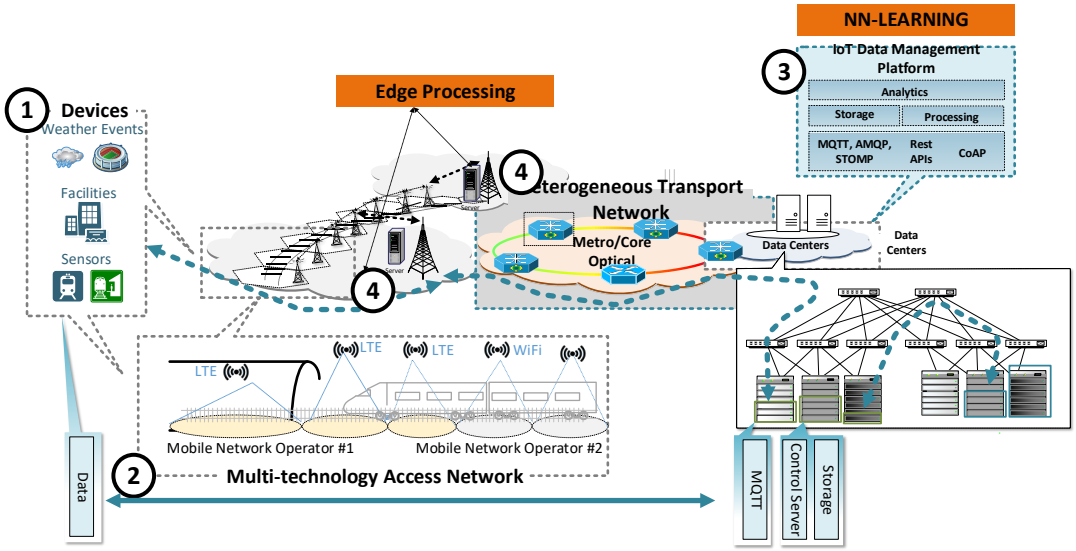


Field Trials

- ***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*

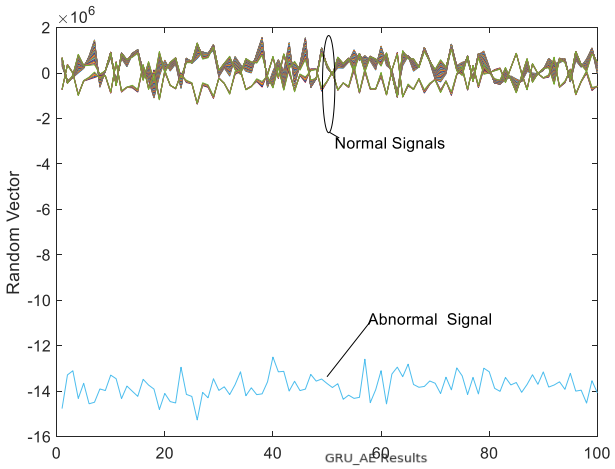






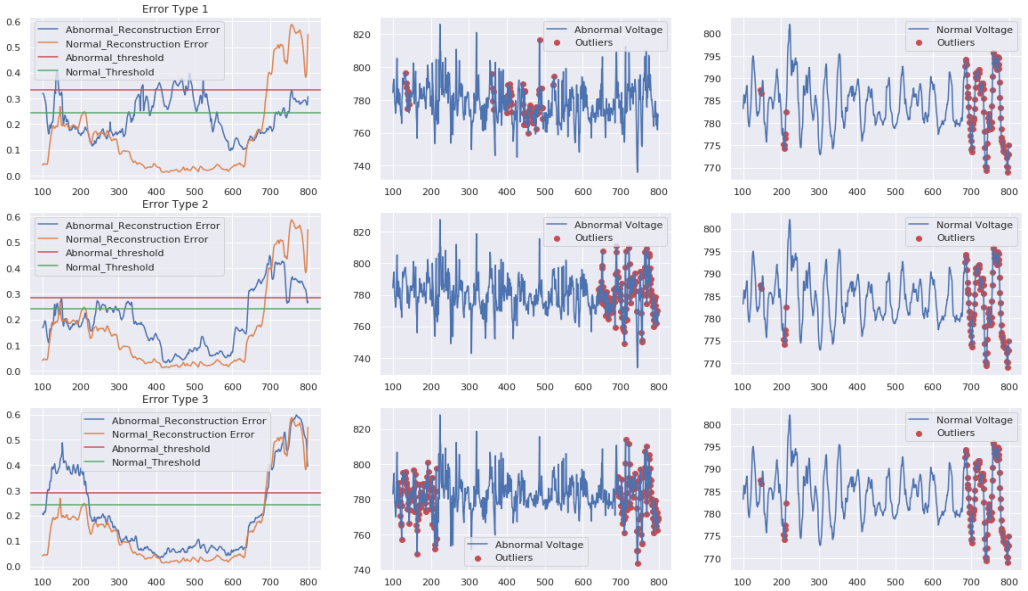
@Network Rail

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



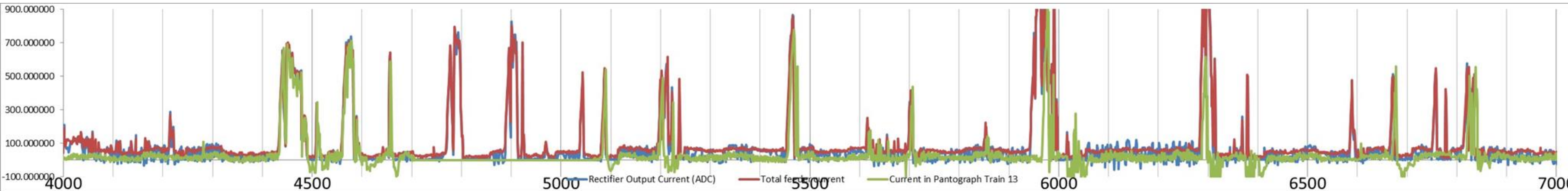
@REIMS

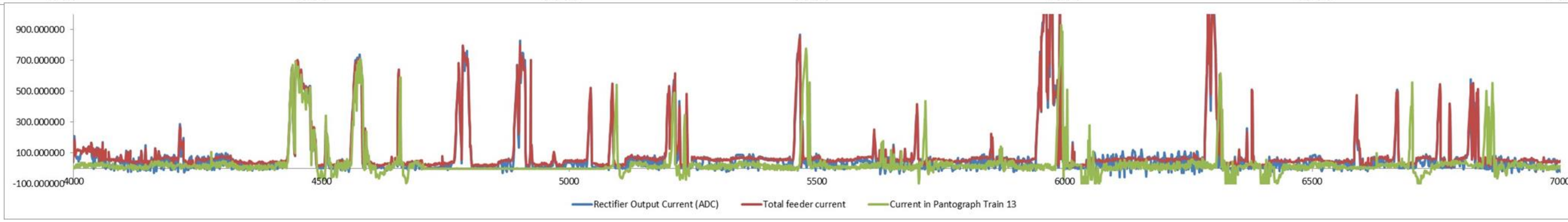
- *Fault detection in an operational tramway system*

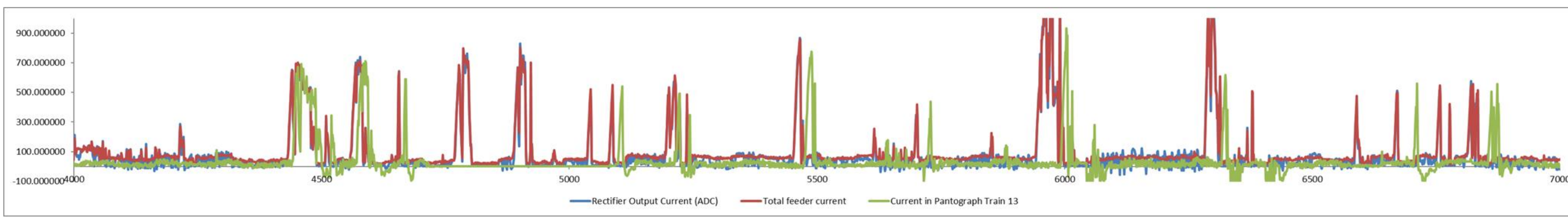


Applications

- Synchronization of measurements



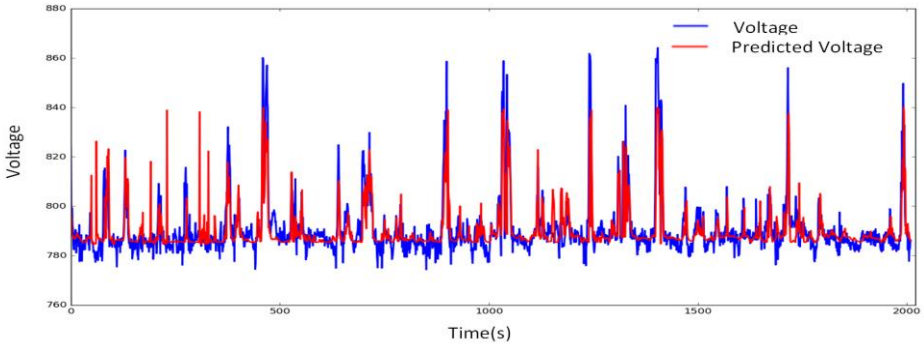




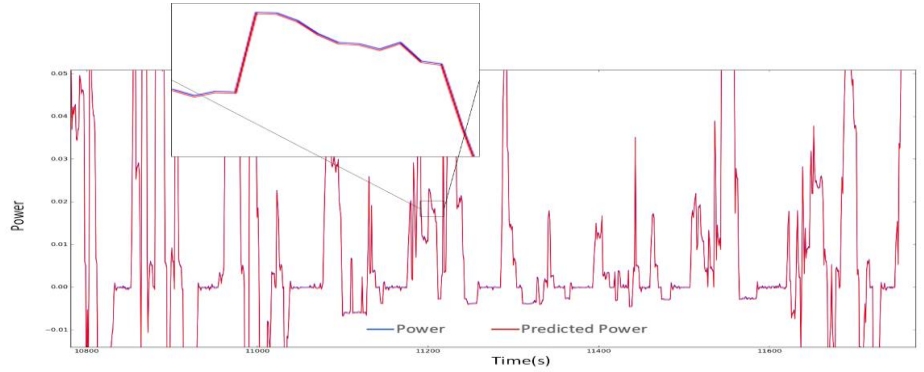
- **Positioning (Without the need of GPS) using telecom network**
  - **In-tunnel positioning using LiFi**

Applications

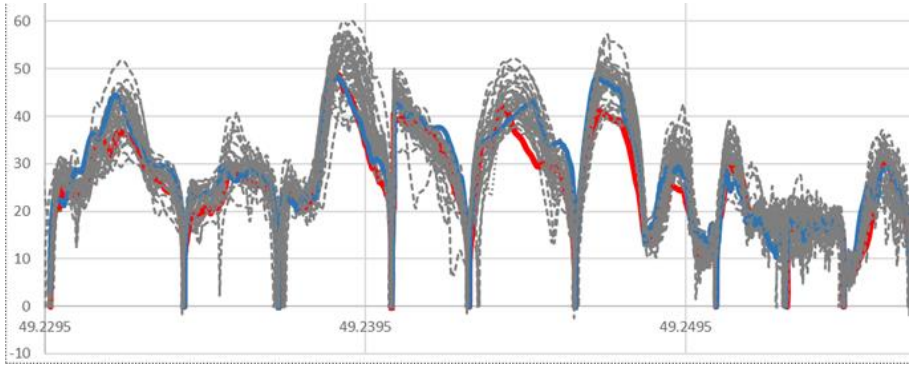
- Estimation of trackside from on-board measurements (software sensors using purposely developed NN models)



- Energy forecasting using LSTM NNs

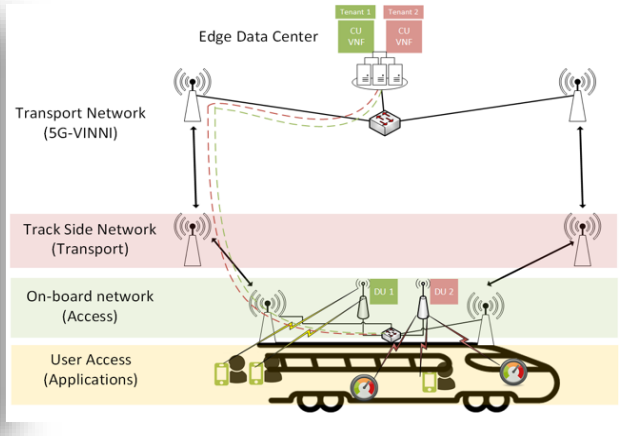


- Optimization (optimal driving profiles) (using Machine learning Techniques)



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



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)