

The Role of the Edge in IoT-Based Railway Diagnostic Satellite and 5G Integrated Networks

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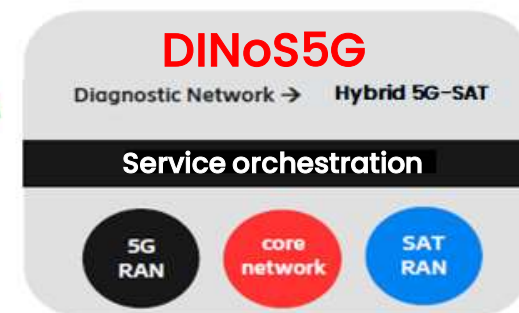
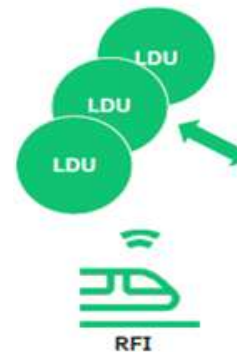
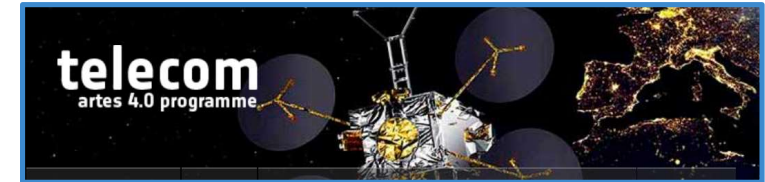
DINoS5G: Satellite-5G based solution to support next-generation railway diagnostic applications

DINoS5G – Diagnostic Integrated Networks of Satellite and 5G

- ESA co-funded Project
- Italian consortium led by RFI
- Smart maintenance of railway infrastructure

A communication platform tailored to the railway infrastructure maintenance

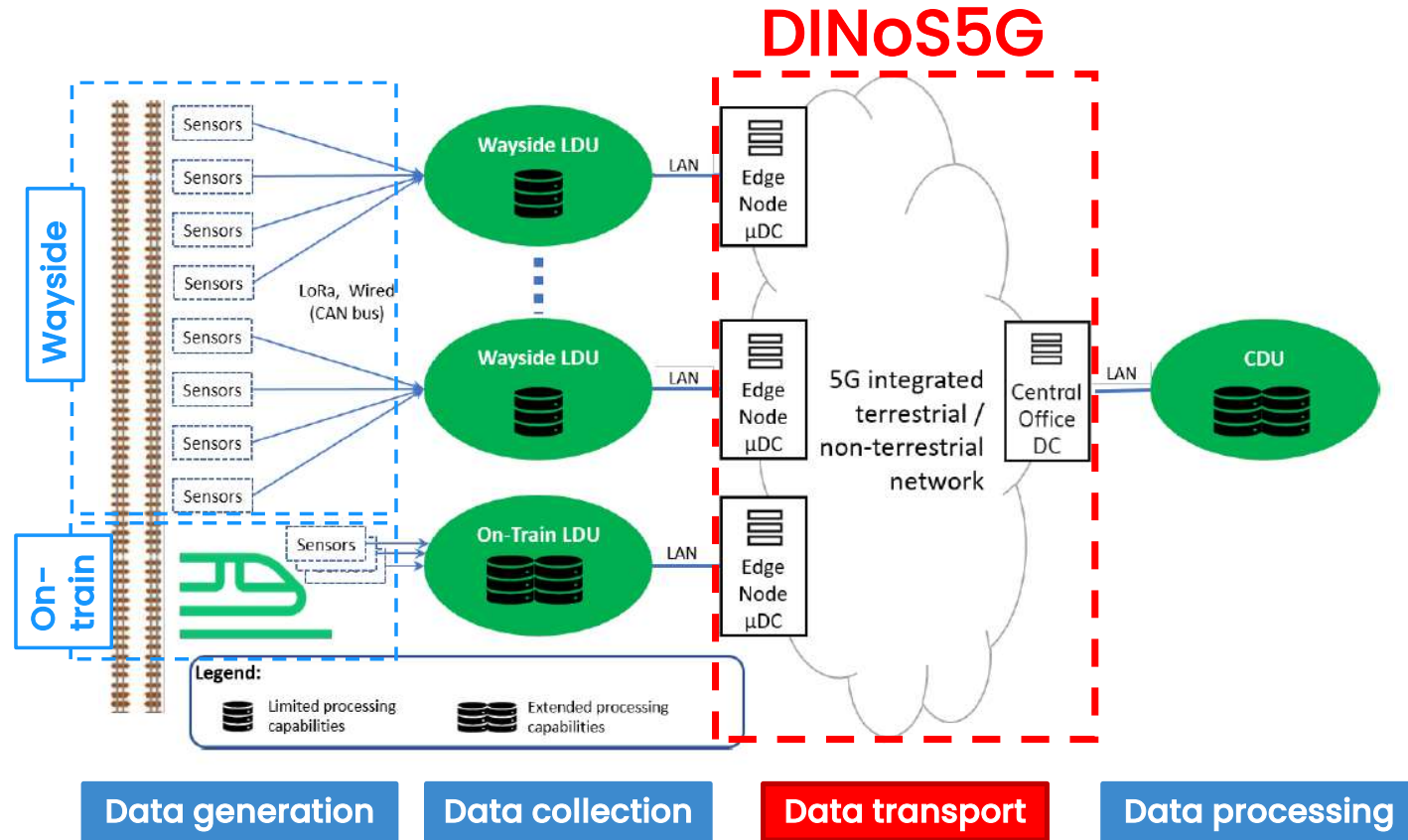
- Efficient and flexible transport of diagnostic data between application endpoints
- Based on hybrid Sat-5G infrastructure
- Prototype design, integration and testing in real environment



The next-generation maintenance of railways

DINoS5G serves the needs of the evolving railway maintenance application

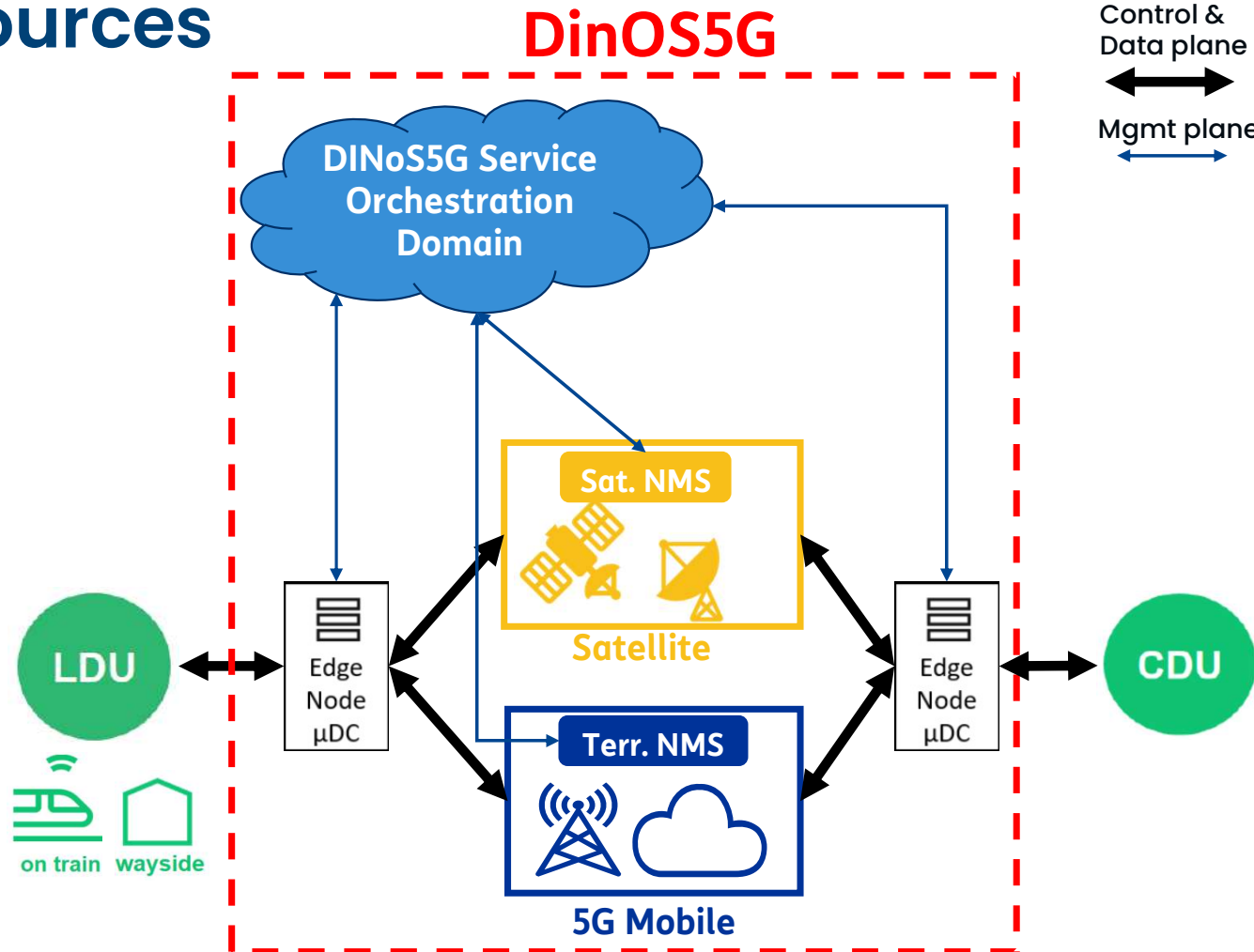
- Massive diagnostic data generation
 - Wayside and on-train
- Efficiently conveyed to few processing units
- Several thousands endpoints (LDUs)
- Ubiquitous service availability
- Transport service tailored to applicative requirements



A platform leveraging on integrated Satellite-5G communication resources

DINoS5G offers transport services over Satellite and 5G

- Both access networks available to the LDUs
- Can be used in alternation or in combination
 - Depending on diagnostic needs and network resource availability in both networks
- RAN selection, data exchange managed by the Edge Node
 - 1 Edge Node per LDU
- Multi-domain service orchestration
 - Enhanced live network nodes (NSO)
 - Designed project-specific elements (AdF)



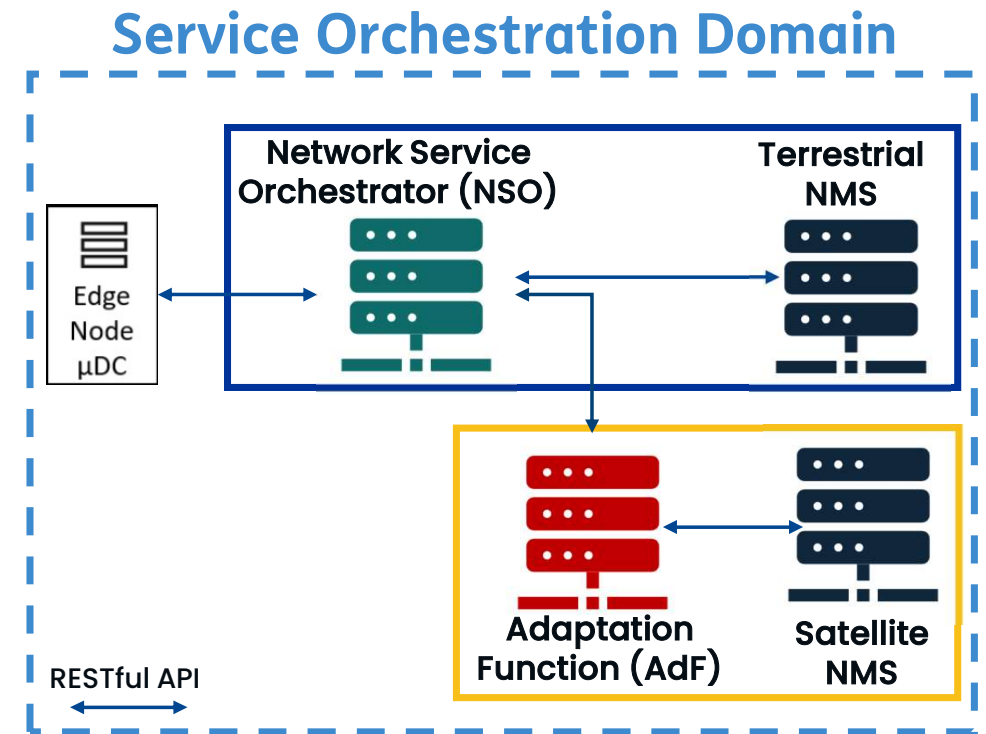
Multi-domain service orchestration

Service Orchestration chain involves live network elements with different levels of customization

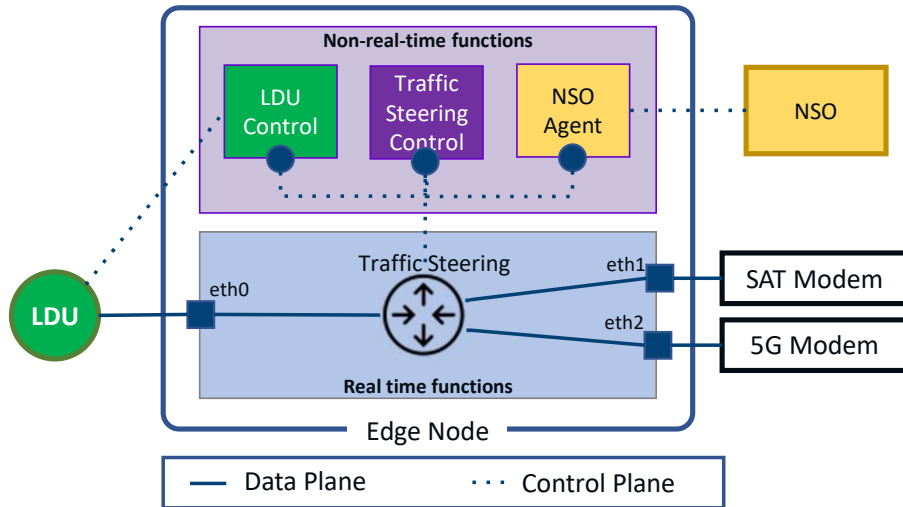
- Network Service Orchestrator
 - Acts as a server to the Edge Node
- Adaptation Function
 - Bridges the semantic gap between satellite NMS and NSO
- Satellite and Terrestrial NMS

Three automation use cases supported

- Satellite resource inventory
 - Provides current channels configuration info
- Network KPI monitoring
 - Provides real time 5G and SAT KPIs
- Satellite service provisioning
 - NSO tries to reconfigure some performance channel parameters



Edge Node – Architectural Design



Inputs from the LDU

- Flow requests

Inputs from the NSO

- Links status/availability
- Asynchronous path imposition

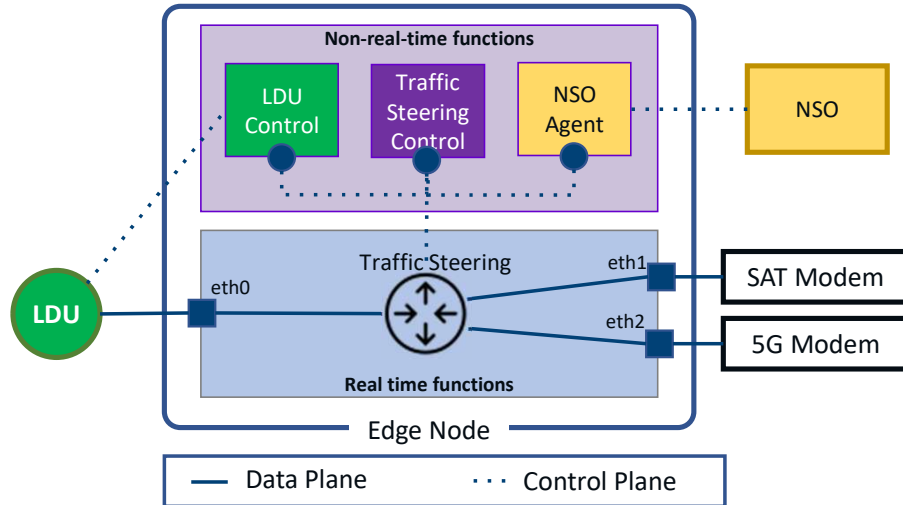
Edge Node main purposes:

- Exploit the SAT / TER interfaces to forward data flows transparently from the LDU point of view

Clear distinction between Control-Plane and Data-Plane

- At any point in time the EN forwards Data Plane traffic according to the flow table
 - In other words: the EN is a **switch** from the LDU point of view
- The EN hosts an engine to update the flow table according to the information available

Edge Node – Traffic Steering info



Flow Requests table (Input from the LDU)

Flow type	Port	Bitrate req	Priority
Class A: Guaranteed bitrate, no priority	xxxx		
Class B: No guaranteed bitrate, no priority	yyyy		
Unscheduled: Non urgent, best effort	zzzz		
Urgent: Guaranteed bitrate, highest priority	kkkk		

Network Link Status table (inputs from NSO/ modems)

Interface	ID	Link capacity	Packet Loss
SAT	Serial Number
5G	Cell ID

Flow Forwarding table

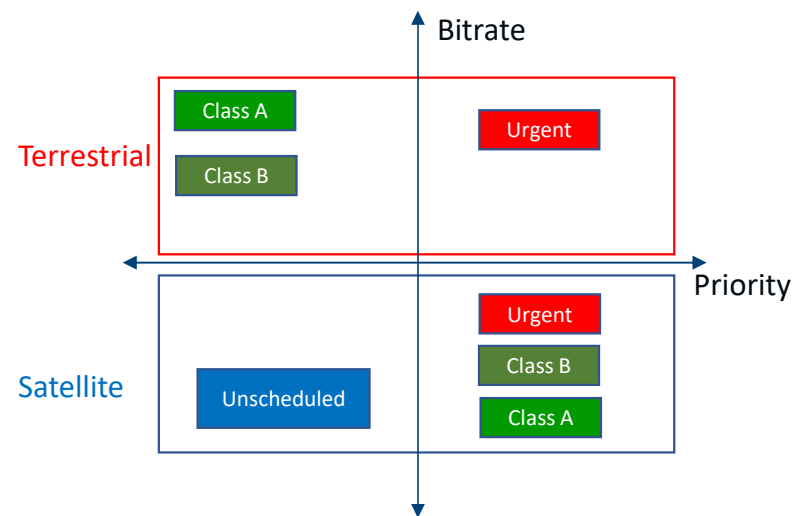
- The EN matches the *Flow Request* and the *Network Link Status* tables and then configures/updates the *Flow Forwarding* table of the switch.

Flow type	TCP/UPD Port	Ingress Port	Output Interface	Priority	Bit-Rate statistics
Guaranteed bitrate, no priority	xxxx	LDU	SAT		
No guaranteed bitrate, no priority	yyyy	LDU	SAT		
Non urgent, best effort	zzzz	LDU	5G		
Guaranteed bitrate, highest priority	kkkk	LDU	5G		
*	*	SAT/5G	LDU		

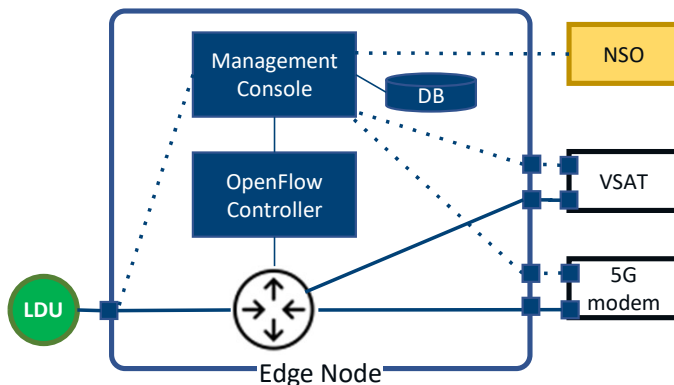
Edge Node – Traffic Steering algorithm

Steps of the traffic steering function

- Read the LDU requirements requests: (bandwidth and priority)
- Read the TERR/SAT network conditions (e.g., currently available capacity)
- Match requirements against link availability
 - If insufficient, request for extra provisioning (through NSO integration)
- Calculate and apply flow rules in the switch to forward each LDU flow to a specific modem



Edge Node – Implementation

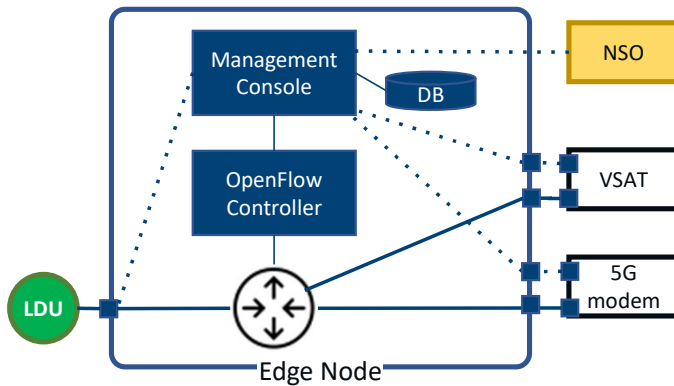


The management console is the place where the traffic steering algorithm is run. It leverages an open-flow controller to control the switch.

The management console consists of:

- **LDU APIs**
 - Information about current flow configuration
- **NSO Integration**
 - Recover information about connections (VSAT and 5G) to perform steering decisions
- **Controller Configuration APIs**
 - Configure requests and change the steering tables (control plane)
- **Database**
 - Store configurations, requests, and latest link information
- **Management UI (console)**
 - Configuration tool for manual interventions

Edge Node – NSO interface



Goal: get/set Network Link Status parameters

Satellite segment

- **Parameters:**
 - **MIR** – Maximum Information Rate; is the upper-bound of the bitrate
 - **CIR** – Committed Information Rate; is guaranteed in clear-sky conditions
 - **IP traffic statistics**
 - TX/RX packets in bytes for TCP, UDP, ...
 - Similar statistics can be retrieved at the EN (from the switch)
 - Currently, not relevant for the traffic steering decision

Terrestrial segment

- Current bandwidth
- Traffic statistics

Provisioning (satellite segment)

- Request for the guaranteed bandwidth allocation (if available)

Extensive on-field trial

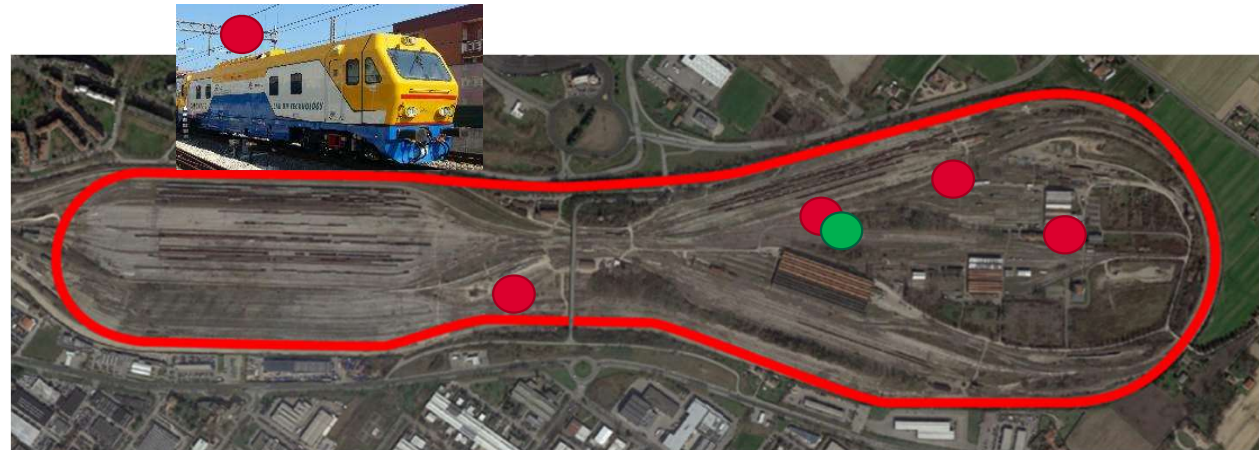
Characterize functionality and end-to-end performance of different delivery chains from LDUs to CDUs

- Wayside and On-train
- Technology-level tests
 - Terrestrial Network (TN)
 - Non-terrestrial Network (NTN)
 - TN-NTN Steering
- Application-level tests
 - Railway diagnostic application use cases
 - KPI measurements

Validate data communication offered by the DINoS5G platform

- Transport plan
- Integrated DINoS5G chain

RFI Diagnostic Train Caronte 2.0



RFI San Donato Test Circuit plant

- Sensors-LDU-Edge Node
- Edge Node-CDU

Wayside LDU



CDU



On-train5G antenna



Wayside 5G antenna



Thank you!

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