Beyond **5G** Multi-Tenant Private Networks Integrating **C**ellular, Wi-Fi and **Li**Fi, Powered by **Ar**tificial **I**ntelligence and In**t**ent Based Polic**y**

Jose Ordonez-Lucena (joseantonio.ordonezlucena@telefonica.com)

Daniel Camps Mur (daniel.camps@i2cat.net)

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Outline

- ❑ Project Vision
- ❑ 5G-CLARITY Overview
- ❑ Architecture Design
- ❑ Pilots and use cases
- ❑ Take-aways & References

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5G-CLARITY at a Glance

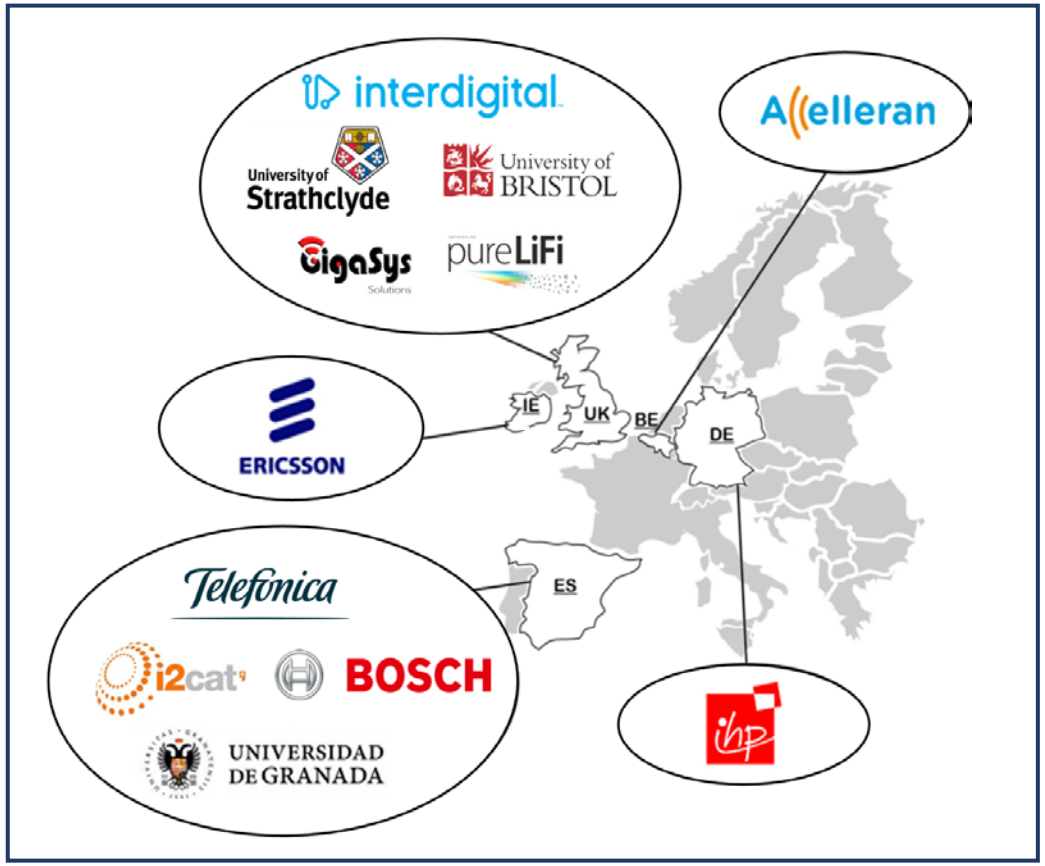
Research Programme
Horizon 2020 5G-PPP ICT-20-2019-2020

Duration
33 months / Nov 2019 – Jun 2022

Total budget
5.7 Million Euro

Project Management Team
Project Coordinator – IHP, Germany
Project Manager – Gigasys Solutions, UK
Technical Manager – i2CAT, Spain

Corsotium
12 partners from 5 countries



Website: www.5gclarity.eu **Social media:** **Contact:** info@5gclarity.com

5G-CLARITY Motivation

- **5G private networks** gaining momentum
  - 3GPP Rel-16 features make 5G systems all-inclusive critical communication platform for industry digitization
  - Incumbent actors (industry verticals, neutral-host and wholesale operators, etc) start making sizeable investment in private 5G networks.
- For the widespread adoption of private 5G networks, it is required:
  - **Seamless interworking between 3GPP 5G access and legacy technologies** (e.g. wired Ethernet, IEEE 802.11) -> backwards compatibility
  - **Small operational costs**-> easy operation and flexible integration with public 5G networks (for CAPEX reduction)
  - **Ever-increasing network capability portfolio**-> ICT-driven network evolution allows for OT-driven service innovation.

The mission of 5G-CLARITY project is to develop and demonstrate a Beyond 5G (B5G) system for private networks integrating **multiple wireless access technologies** including 5G, Wi-Fi and LiFi technologies, all operated through **AI-based autonomic networking**.

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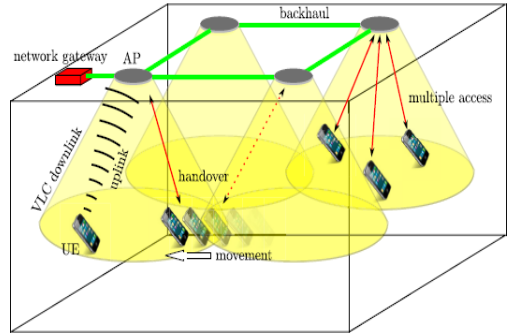
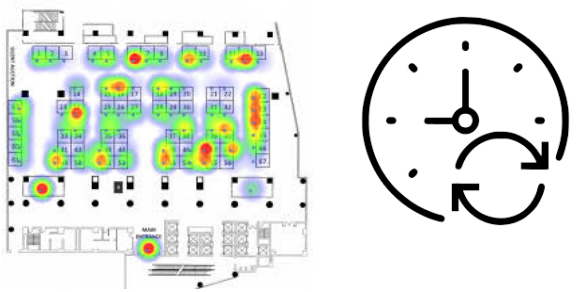
5G-CLARITY Technical Innovations

LiFi technology

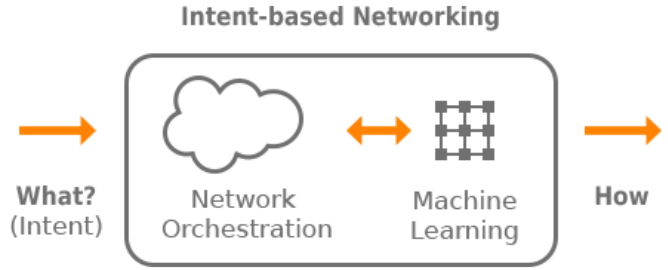


5GNR/Wi-Fi/LiFi multi-connectivity framework

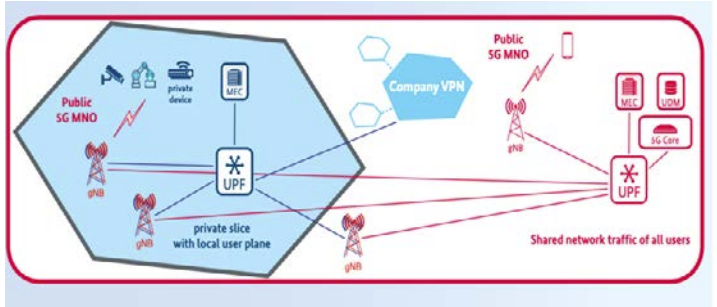
Cm-level localization and synchronization capabilities



AI-driven and **intent-based** network management

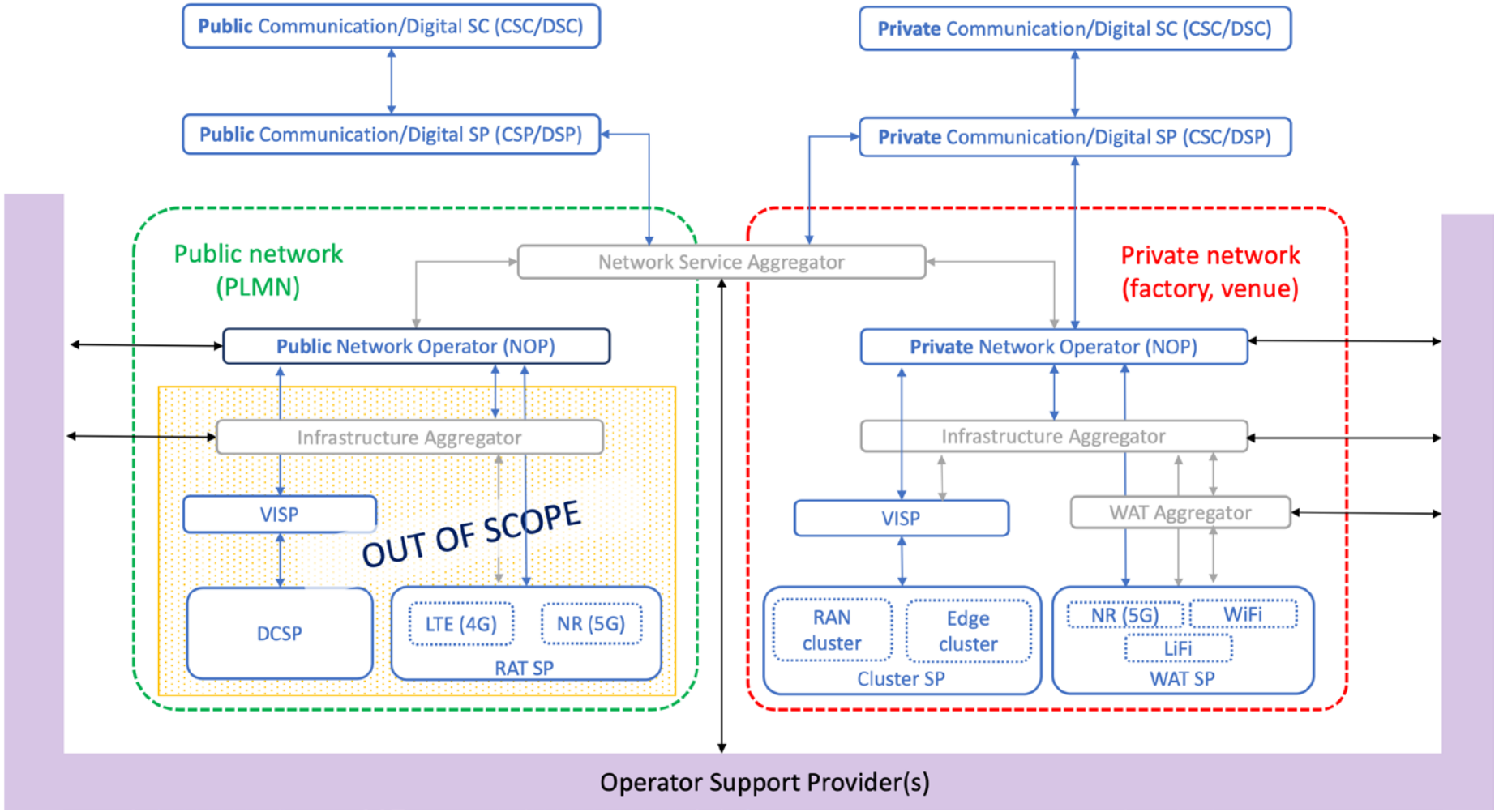


Integration and interoperation of **private and public networks**



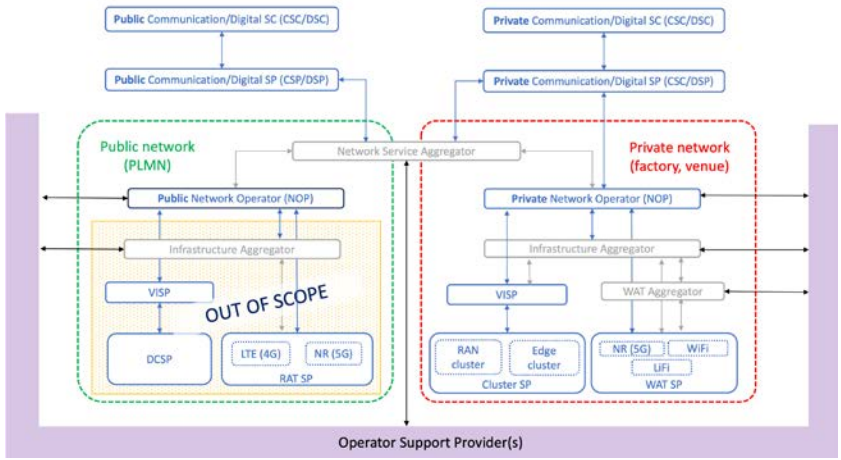
5G-CLARITY Actor Role Model

- Going beyond 3GPP/5G-PPP scope



5G-CLARITY Service Offering

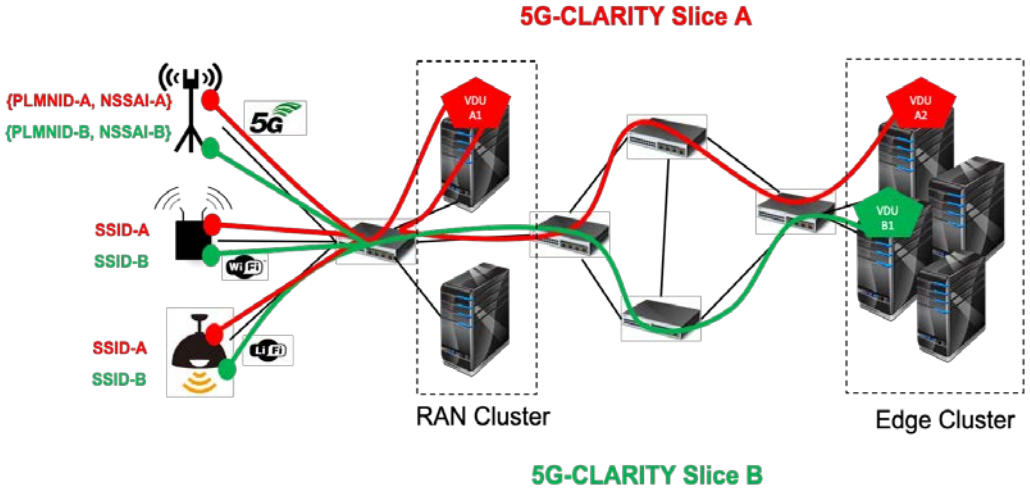
- New roles means innovative service delivery models and unleashes rich business relationships.



Service Delivery Model	Provider → Customer
WAT as a Service	Private NOP → Public NOP
NFV Infrastructure as a Service	Private NOP → Public NOP
	Public NOP → Private NOP
Slice as a Service	Private NOP → Public CSP/DSP or private NOP
	Public NOP → Private NOP
Intelligence as a Service	Operation Support Provider → Private NOP
	Operator Support Provider → Public NOP

- 5G-CLARITY slicing
  - 5G-CLARITY slice = {5G-CLARITY wireless service + 5G-CLARITY compute service + 5G-CLARITY transport service}
  - 5G-CLARITY slices (**on-premise infrastructure slices** for multi-tenancy support) vs 3GPP slicing (**network slices** for multi-service support)
- 5G-CLARITY tenants

Private CSP/DSP | Public CSP/DSP | Public NOP (MNO) | Hyperscaler



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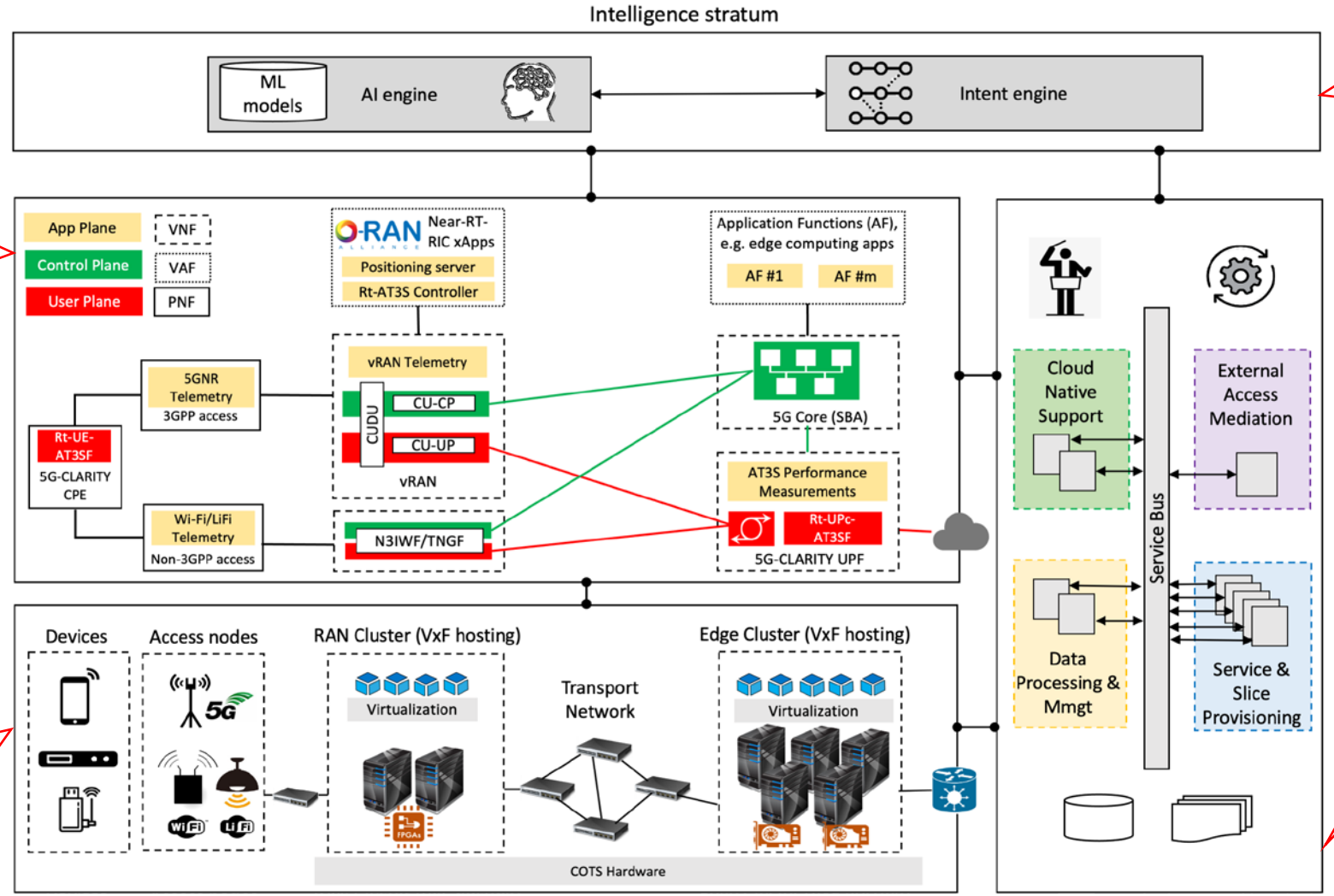
5G-CLARITY System Architecture



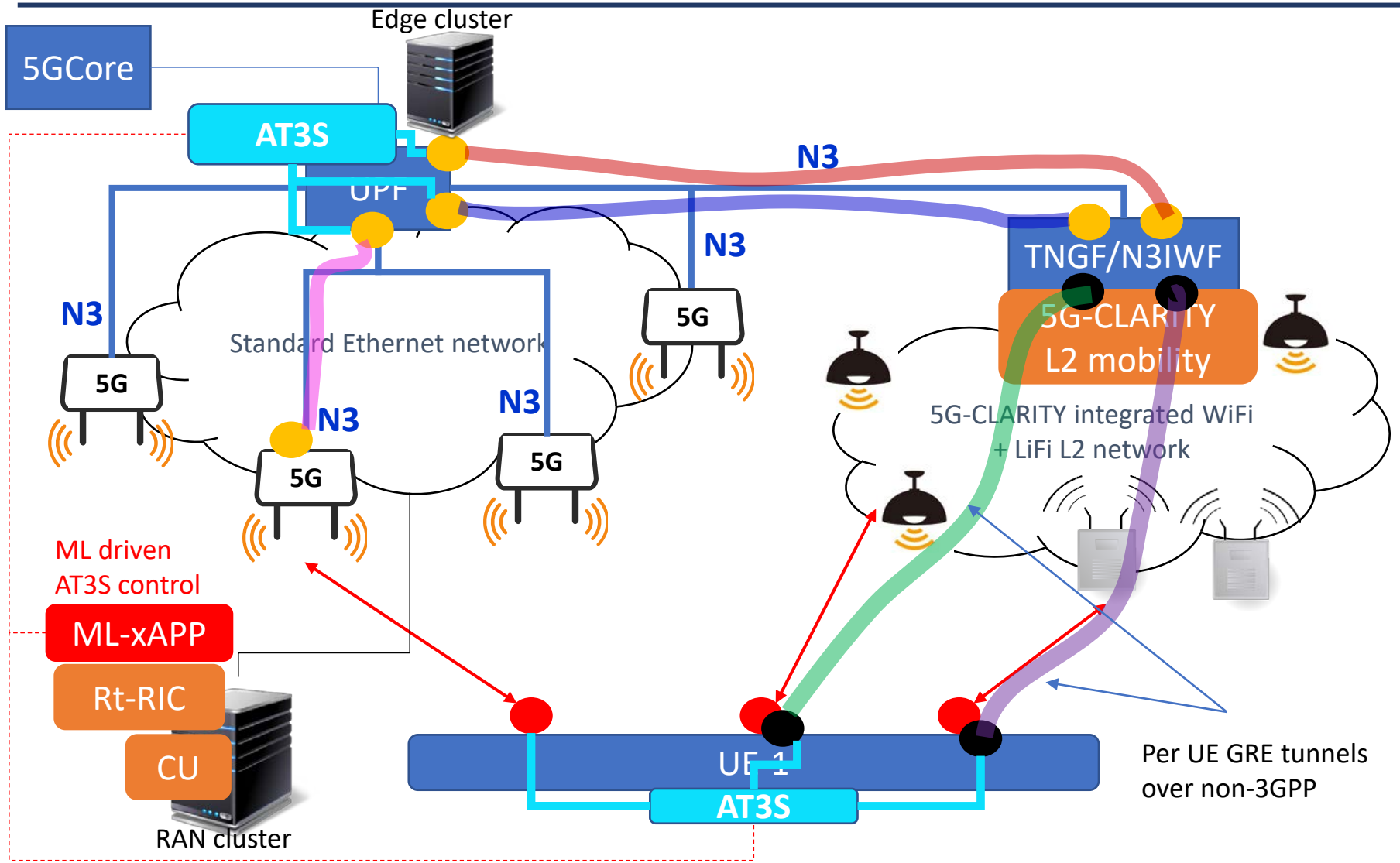
- Control and User Plane Separation (CUPS)
- Cloud-native VxFs
- RAN functional splitting
- Integration with O-RAN
- Multi-WAT protocol stack

- Cloud-native and service oriented
- Language/ML framework independence
- Ease of use

- Support of multiple types of devices
- Coexistence of purpose-built and COTS HW
- In-network computing
- Clustered NFVI
- Industry-ready transport network (Ethernet + TSN)

- Service Based Management Architecture (SBMA)
- Extensibility
- MF statelessness
- Model-driven operation
- Reproducibility
- Service capability exposure

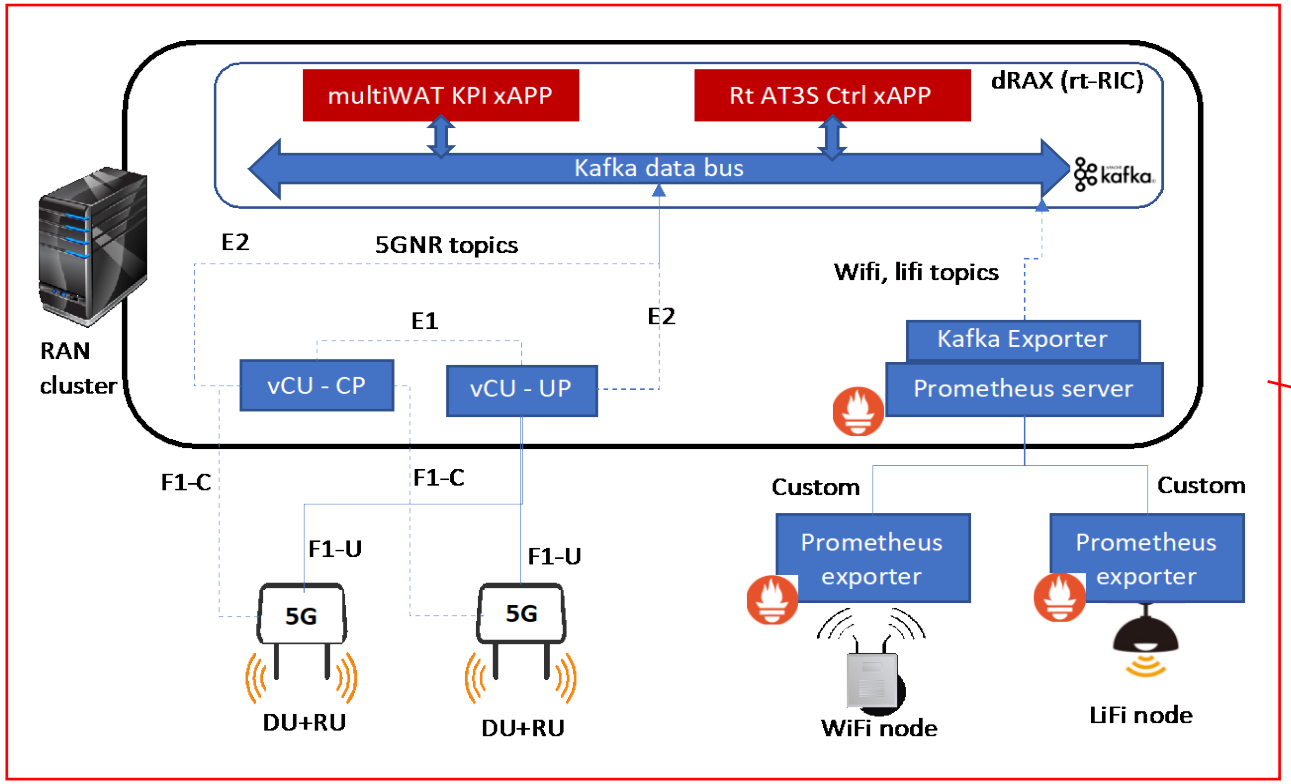
#1a - Multi-connectivity framework

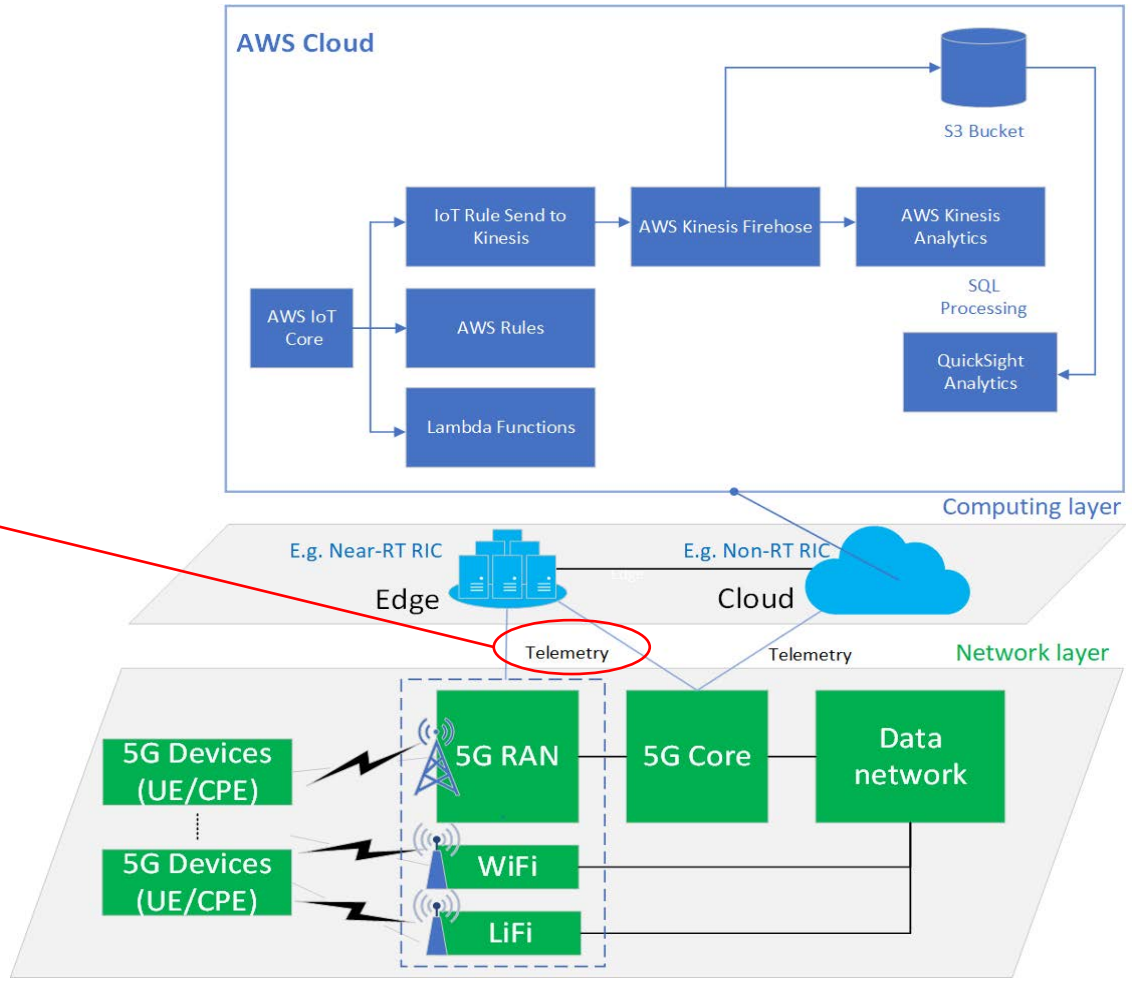


- Adhering to **3GPP Release 16** (AT3S) and **O-RAN** (rt-RIC & xApps)
- **WiFi+LiFi integration** through TNGF/N3IWF through single SDN enabled L2 network
- **ML-driven control of AT3S bindings** and policies

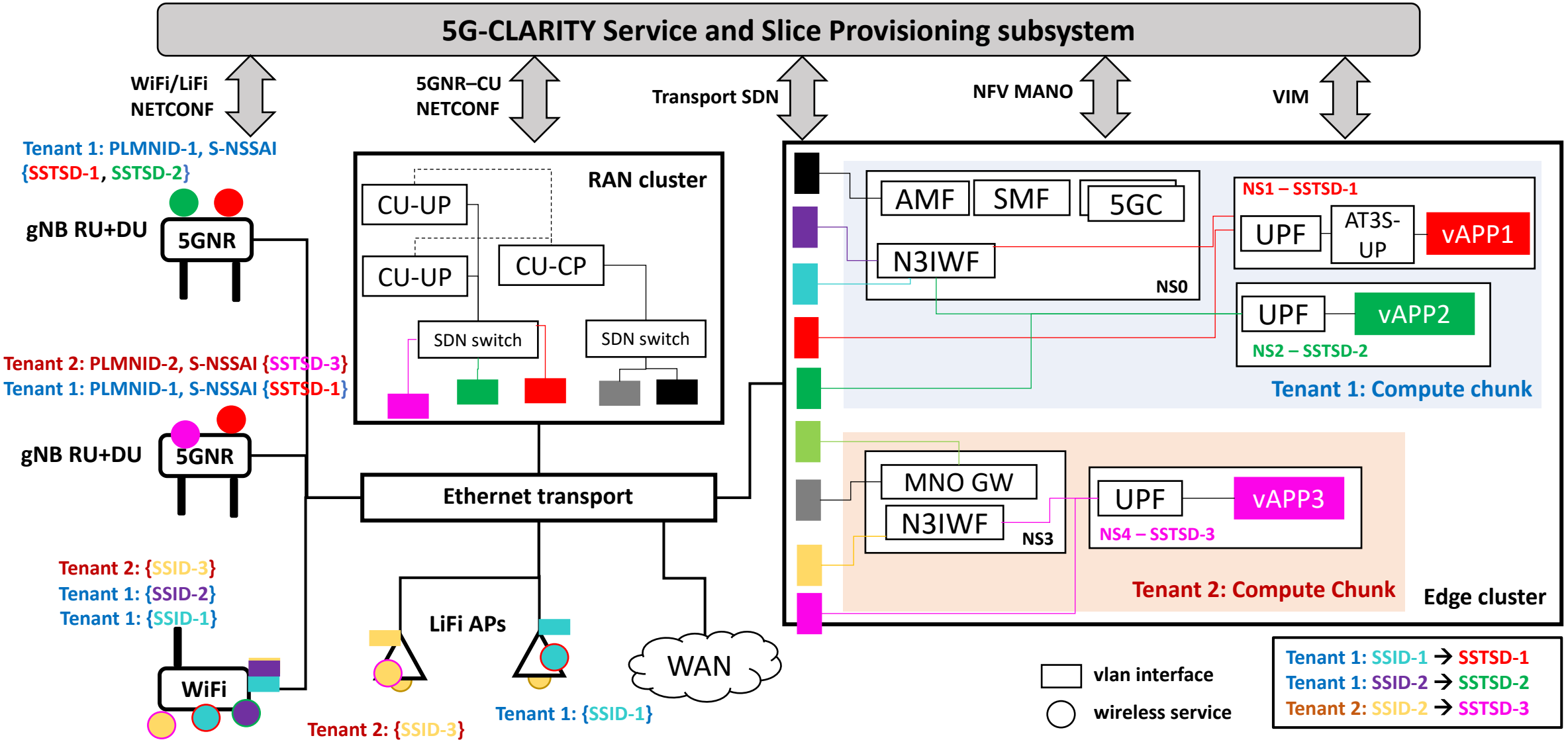
#1b – non-real-time Multi-WAT Telemetry

- Example of a cloud-based solution



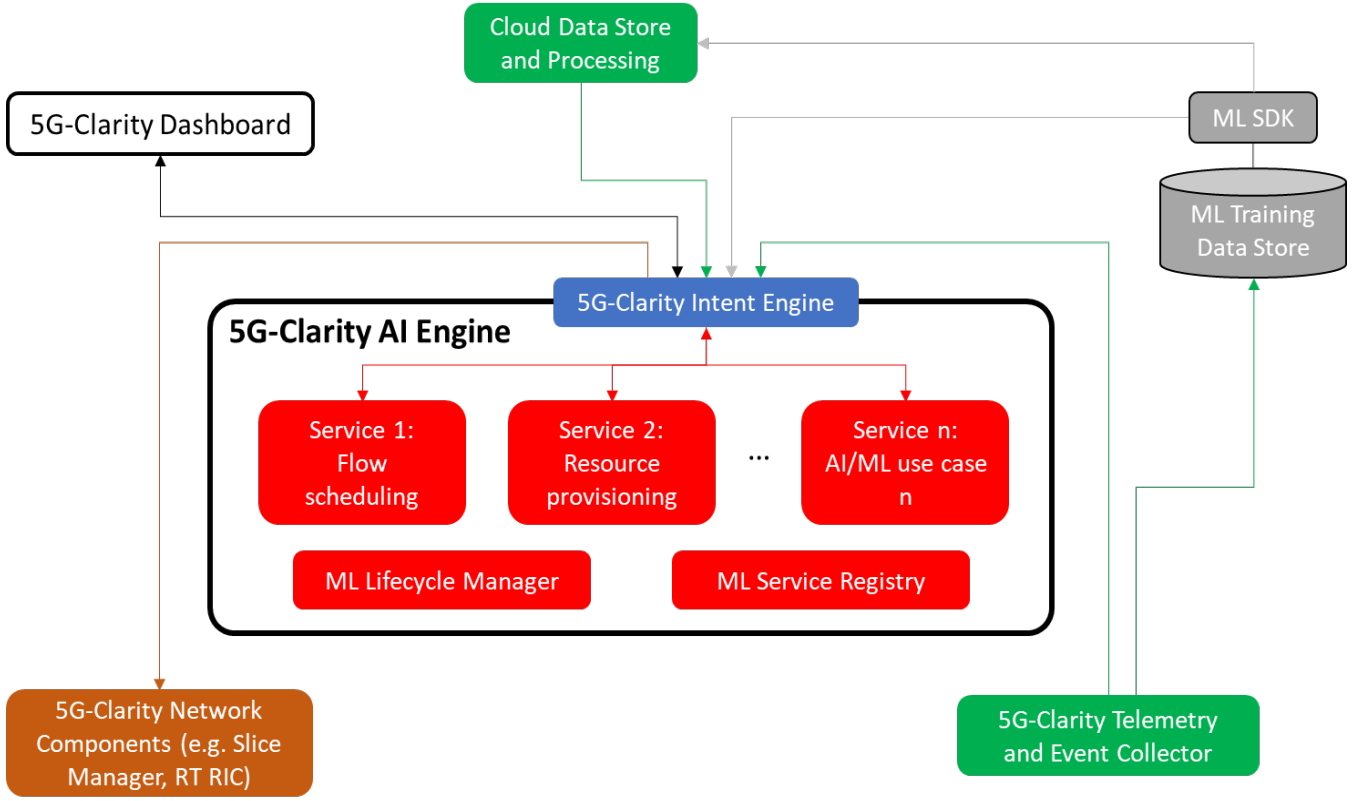


#2 - 5G-CLARITY slicing approach

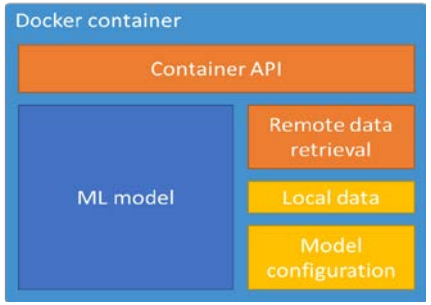


#3 - AI and intent based management

- 5G-CLARITY intelligence stratum based on **AI engine** (ML models) mediated with **intent engine** (simplicity for non-expert users)



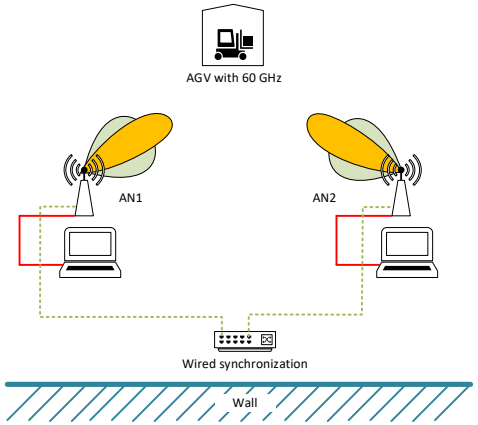
- **ML models containerisation** using Docker containers



- **5G-CLARITY ML Algorithms**
  - Predicting SLA violations/success rate
  - RT-RIC: AT3S traffic routing/handover
  - RAN slicing in multi-tenant networks
  - Optimal network access problem
  - Optimal compute offloading
  - Indoor ranging with nLoS awareness
  - Resource provisioning in a multi-WAT
  - Dynamic transport network setup and compute resources provisioning
  - AI-based defect-detection in a smart factory

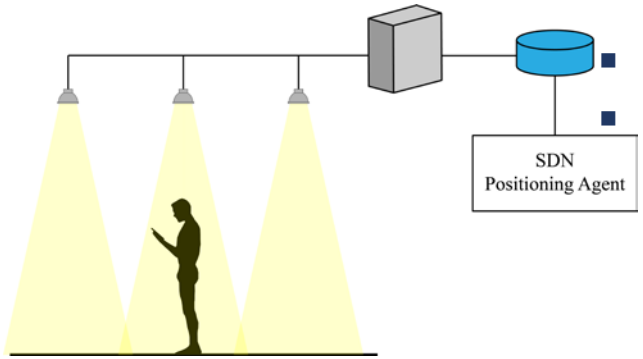
#4 - Hybrid positioning

❑ mmWave + Sub-6 GHz positioning



- **Methods:** DL-TDOA, UL-TDOA, TWR
- **Sub-6 GHz** expected precision of **1 meter or better**
- **mmWave** expected precision of **1 centimeter or better**

❑ LiFi positioning

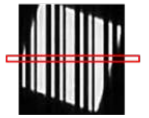


- **Methods:** RSSI
- **LiFi** expected precision of **1 meter or better** (theoretically centimeter precision possible)

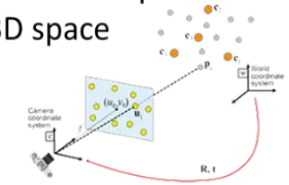
❑ Optical Camera Communications

STEP 1: Take photo and process LED positions

STEP 2: Decode light ID and lookup position

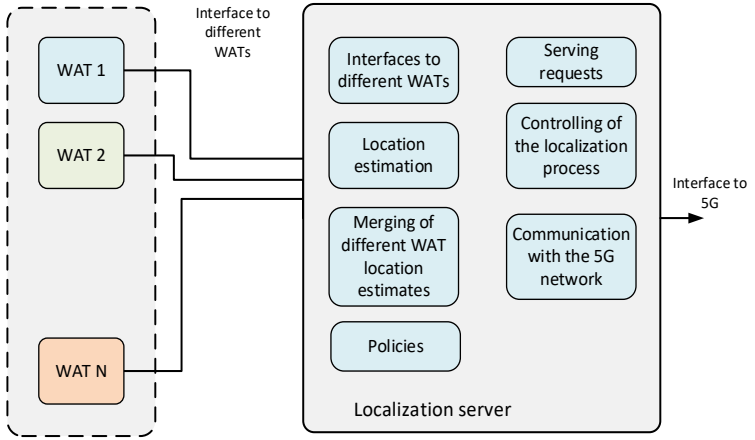


STEP 3: Map 2D to 3D space



❑ Positioning server

- Sub-6 GHz
- mmWave
- 5G NR
- LiFi
- OCC



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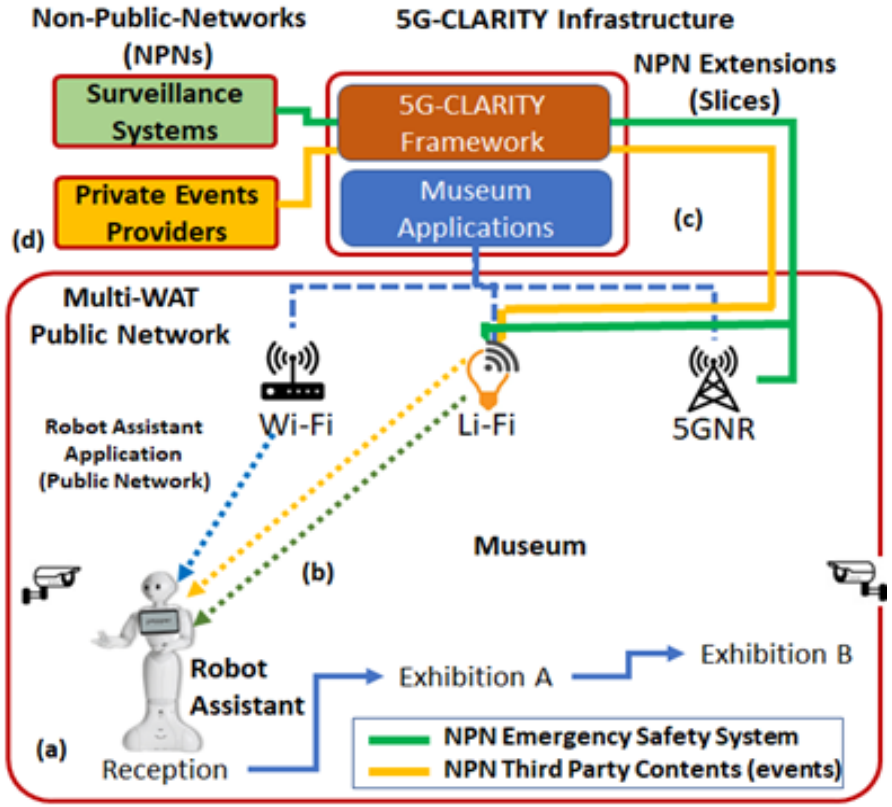
Smart Tourism Pilot: UNIVBRIS

❑ Use Case:

- Museum robot assistance



❑ Venue:

- M-Shed museum of Bristol city council

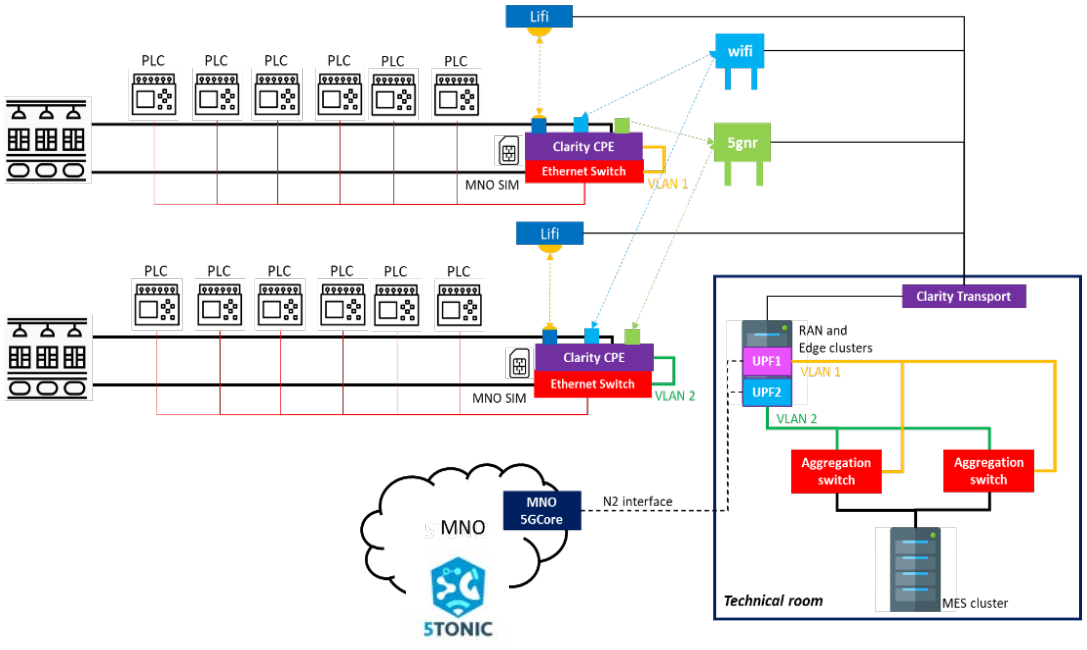
❑ Three main narrratives

- Guide robot welcomes and guides visitors to requested exposition
- On-demand surveillance of suspicious activities in the museum
- On-demand 3rd party content for scheduled private events

Industry 4.0 Pilot: BOSCH

❑ Use Case:

- Connecting MES enabled production lines



❑ Venue:

- BOSCH factory, Aranjuez (Madrid)

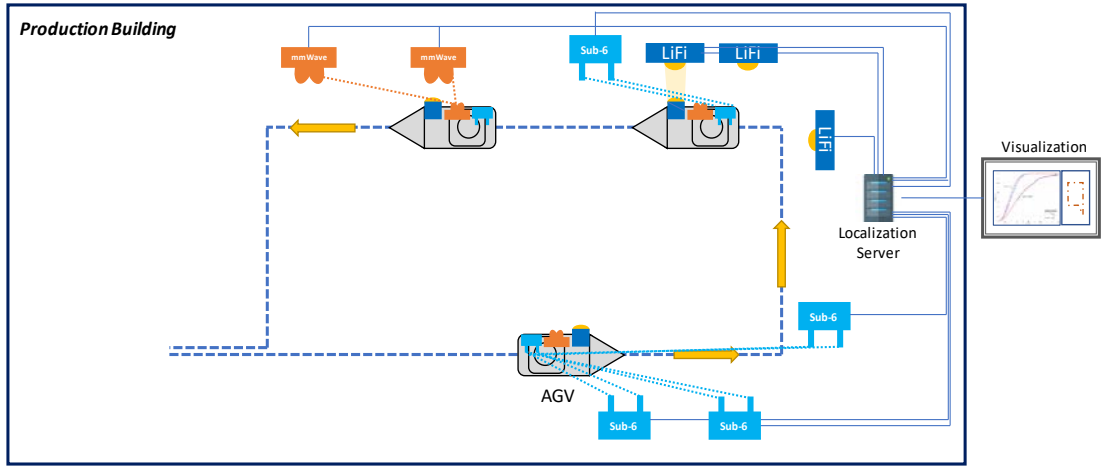
❑ Three-step validation setup

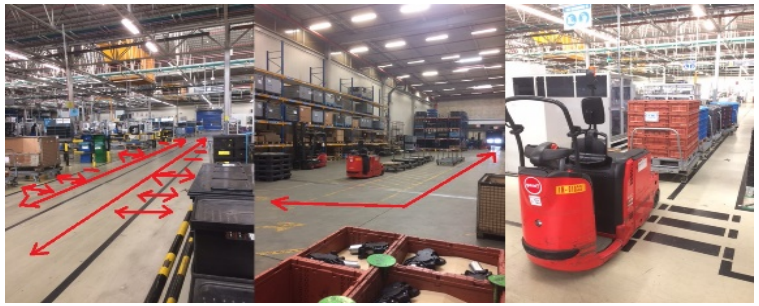
- Portable production line testbed
- In-factory setup (w/o real OT infrastructure)
- In-factory production line (w/ OT infrastructure)

Industry 4.0 Pilot: BOSCH

❑ Use Case:

- Tracking AGV trajectories





❑ Venue:

- BOSCH factory, Aranjuez (Madrid)

❑ Real-time, cm-level AGV tracking with hybrid positioning

- mmWave + sub-6Ghz positioning (DL-TDOA, UL-TDOA, TWR)
- Lifi positioning (RSSI)
- Optical Camera Communications (OCC)

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Take-aways & References

- **5G-CLARITY** project is developing a system for B5G private networks featuring:
  - 5GNR+Wi-Fi+LiFi multi-connectivity framework
  - High precision localization capabilities, based on the use of hybrid positioning
  - Multi-WAT slicing
  - Deployment and operation of multiple NPN scenarios, with different private-public network settings
  - AI based and Intent driven network & service management

- Smart Tourism and Industry 4.0 pilots to be demonstrated Q2 2022
  - Museum robot assistance (Bristol, UK)
  - Connecting MES enabled production lines (BOSCH, Spain)
  - Tracking AGV trajectories (BOSCH, Spain)

- Main deliverables available at www.5gclarity.com :
  - System architecture: D2.2
  - Multi-connectivity framework and positioning initial design: D3.1
  - Slicing design: D4.1
  - 5G-CLARITY use cases: D5.1