

Universidad de Málaga
Ingeniería de Comunicaciones, Mobilenet

Málaga center for experimentation and NTN

Sergio Fortes

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UNIVERSIDAD
DE MÁLAGA

Universidad de Málaga
Ingeniería de Comunicaciones, Mobilenet

mobilenet

Mobile & Aerospace Networks Lab

Sergio Fortes, Raquel Barco



sergio.fortes@uma.es, rbarco@uma.es



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- 1. Who is this guy?**
- 2. Mobilenet**
- 3. Infrastructure**
- 4. Experiences with testbed-as-a-service**
- 5. The future**
- 6. Wrap-up**

Who is this guy?

Who is this guy?

- **Sergio Fortes – SERGIO.FORTES@UMA.ES**
- Telecommunications Engineer
- Master Thesis in **DLR** → Machine Learning
- Internship in **CNES** → Aeronautical satellite communications
- YGT in the European Space Agency (**ESA**) → Iris program, aeronautical satellite communications: protocols, security



Who is this guy?

- Satellite Communications Engineer in **Avanti Communications** → satcom



- Return to the **University of Malaga (2012):**

- Research: AI for Telecom
- 3 years working with Ericsson



- Former Deputy Vice-chancellor of Knowledge Transfer of UMA
- Founder of Albor Space and MST



mobilenet

Mobile & Aerospace Networks Lab

mobilenet.uma.es

- Origins: 2000 - Nokia.
Director: Raquel Barco
- 17+ patents with companies
- 15 mEUR+ in 10 years (>50% private funding)
- Applied R&D on AI, 5G, SATCOM, TSN, Cloud robotics, emergencies, localization, health ...

We are...

Private-public collaboration



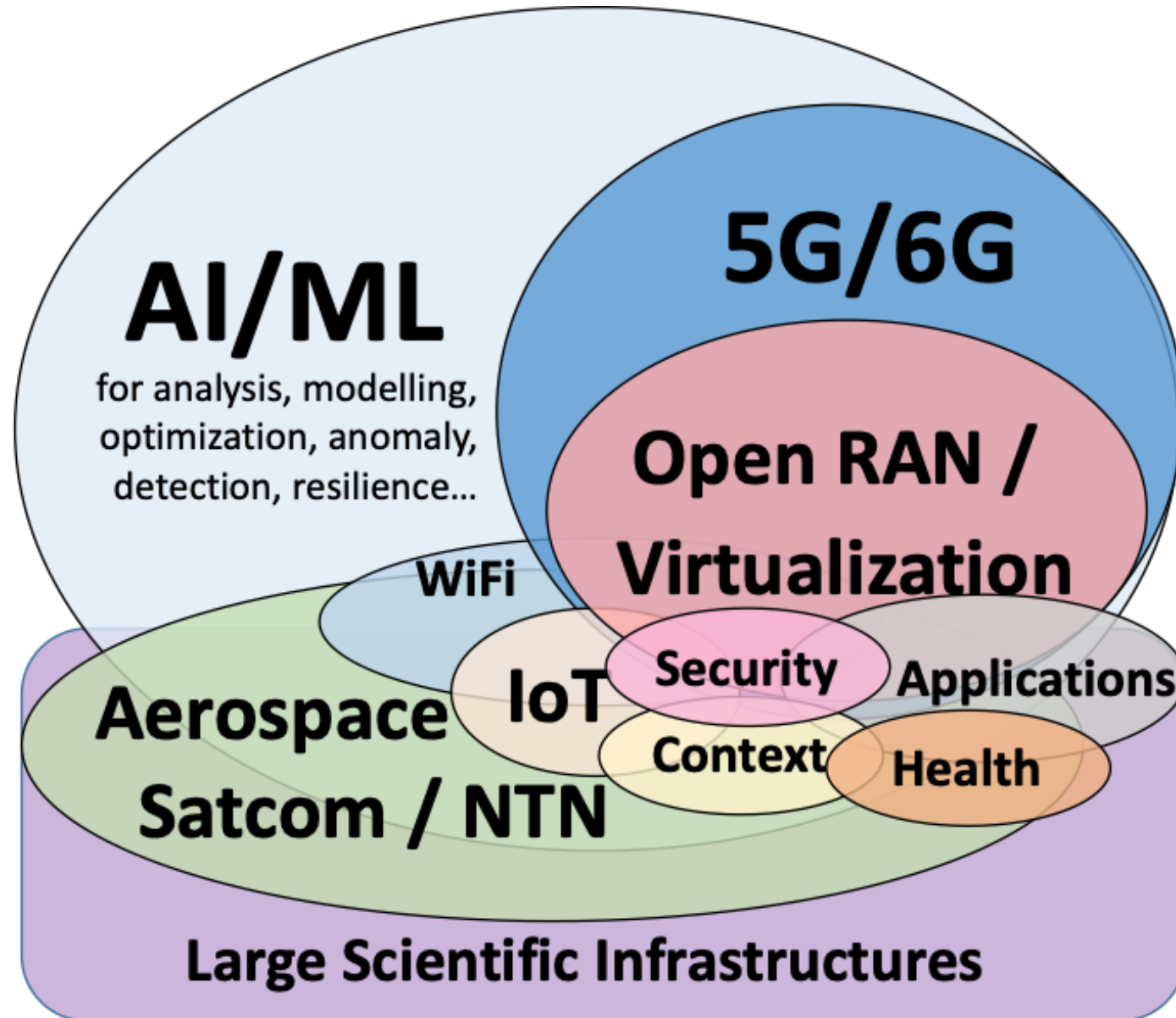
...who we are



40+ staff



....what we do



Example projects

mobilenet
Mobile & Aerospace Networks Lab



Ene'12-Jun'17
> 10 M€

+ Oct'20-Jun'23
>1.5 M€

+ 5G-VEC
Autonomous Vehicles

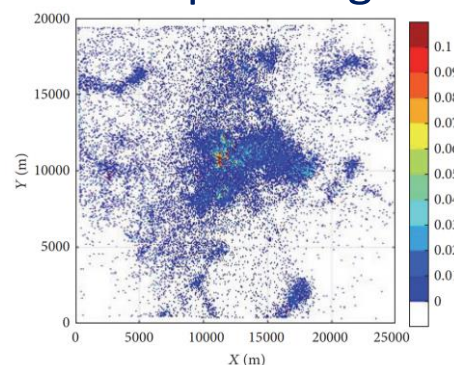
• Network Planning

- Automatic indoor site selection
- Measurement-based propagation and capacity models
- Power/tilt/PCI (re)planning
- Traffic forecast
- KPI estimation



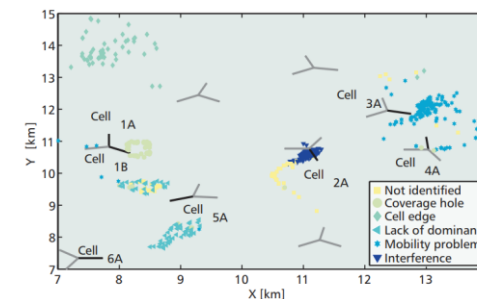
• Optimization

- Neighbors, coverage, capacity, energy...
- Mobility robustness, load balancing, intersystem HO control
- Link adaptation, admission and congestion control
- QoE monitoring/modelling
- Event-based planning



• Healing

- Performance monitoring assessment and prediction
- Fault/anomaly detection, RCA, compensation
- Drive test (e.g., P3 Connect) and trace analysis
- Geolocation
- Transform-based analysis



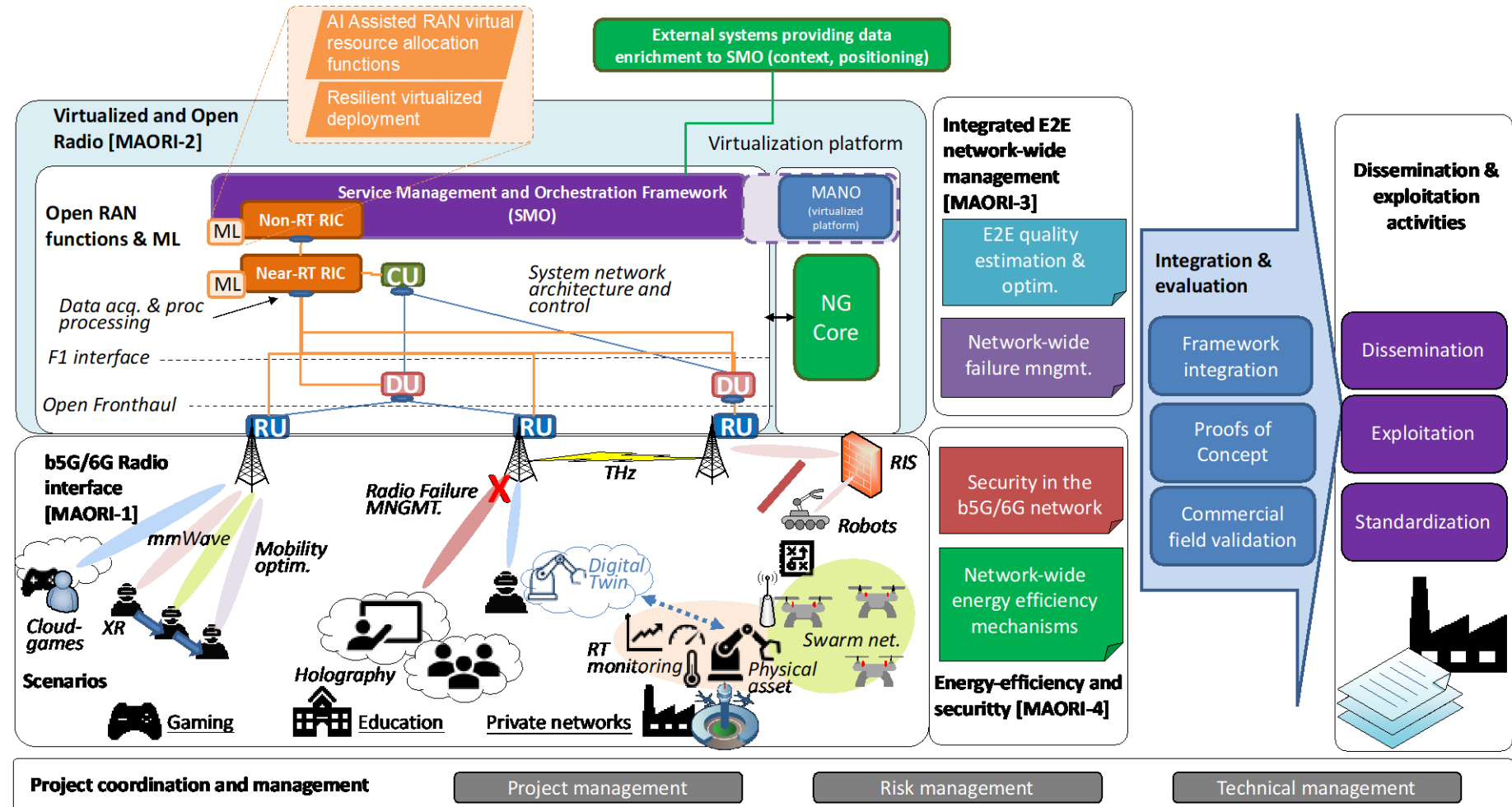
Key projects & Mobilenet tasks

MAORI- Massive AI for the Open Radio b5G/6G network

Jan'22-Dec'24,
2.42 M€



- Open and virtualized RAN focus
- R&D fields
 - 6G radio
 - Virtualized resources assignments and troubleshooting
 - E2E quality estimation and optimization
 - Security and energy saving



Key projects & Mobilenet tasks

MAORI- Massive AI for the Open Radio b5G/6G network

Jan'22-Dec'24,
2.42 M€



Funded by the
European Union
NextGenerationEU



GOBIERNO
DE ESPAÑA

MINISTERIO
DE ASUNTOS ECONÓMICOS
Y TRANSFORMACIÓN DIGITAL

SECRETARÍA DE ESTADO
DE TELECOMUNICACIONES
E INFRAESTRUCTURAS DIGITALES



Plan de Recuperación,
Transformación y Resiliencia

- Project coordinator: University of Málaga / Mobilenet

- Consortium profiles (already fixed budget per profile):

1. Test and measurement equipment company → Keysight

2. Testing/Emulation, inspection and certif. company → Dekra

3. Technology Consultancy → Laude

4. Vertical Service Provider / Consultancy → Aertec

5. Vertical infrastructure operator

6. Private network equipment vendor

7. Technology Consultancy in advanced AI mechanisms / Quantum Machine Learning → Multiverse





FLEXIA

ESTUDIO Y DESARROLLO DE SOLUCIONES DE IA CONFIABLE, INTEROPERABLE Y SEGURA PARA LA AUTOMATIZACIÓN INDUSTRIAL INTELIGENTE



Programa MISIONES CIENCIA E INNOVACIÓN 2025

CON LA COLABORACIÓN DE:



Ene'26-Dic'28,
(UMA: 465 k€)



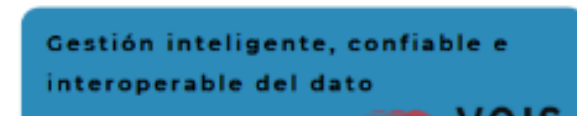
- MISIONES 25
- Telecommunications
- Security
- Positioning

PT1



Estudio de especificaciones y toma de requisitos

Gestión inteligente, confiable e interoperable del dato



PT2

IA eficiente y confiable en el edge



PT3

PT4



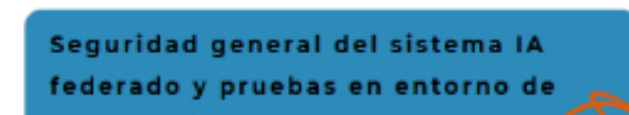
Sistemas autónomos para la robótica inteligente en industria automatizada

PT5

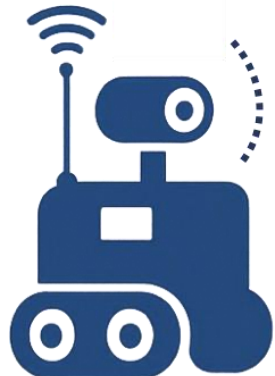


Orquestación y gestión de modelos IA mediante Federated Learning

Seguridad general del sistema IA federado y pruebas en entorno de laboratorio



PT6

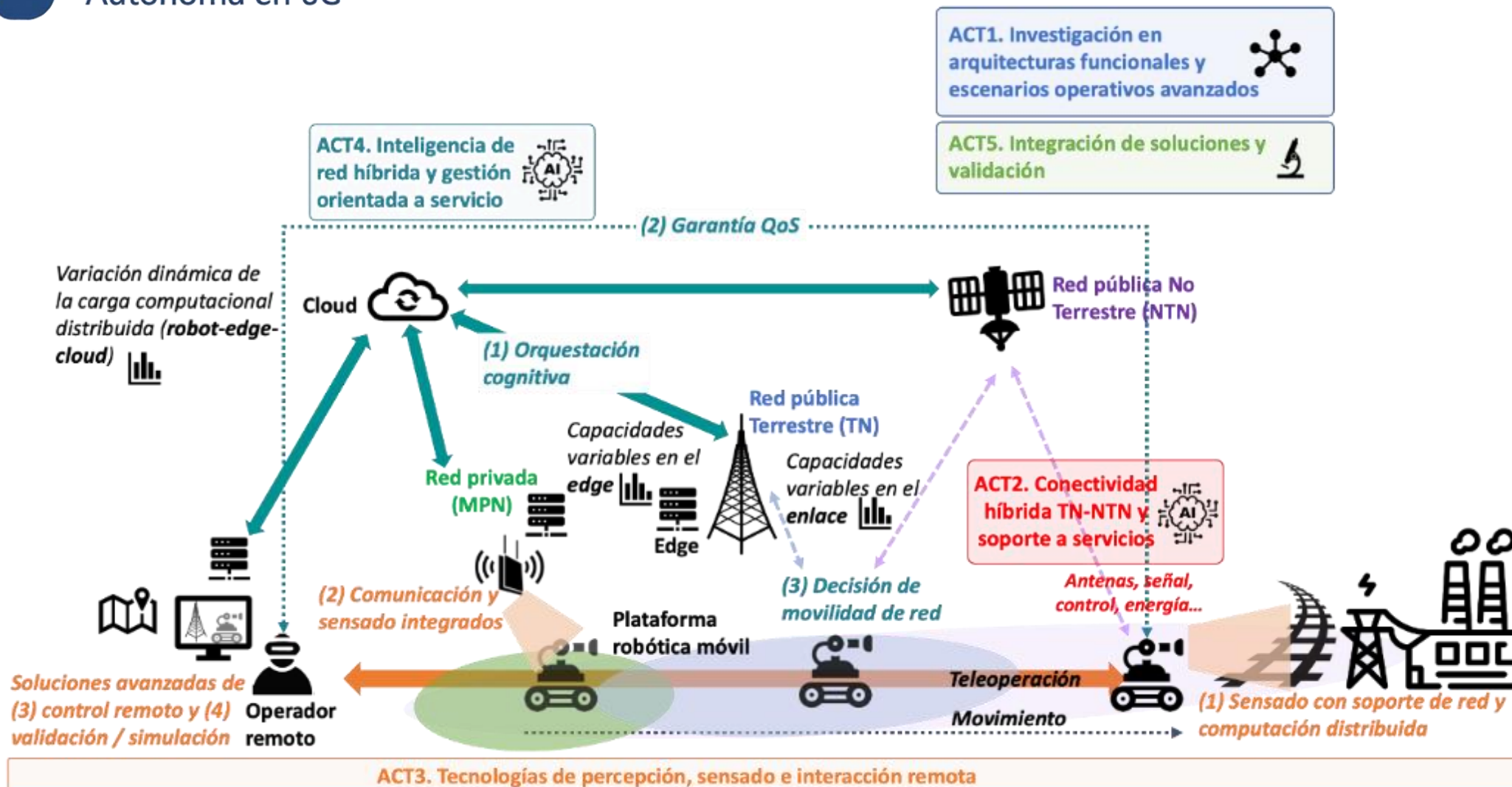


INSPIRA-6G

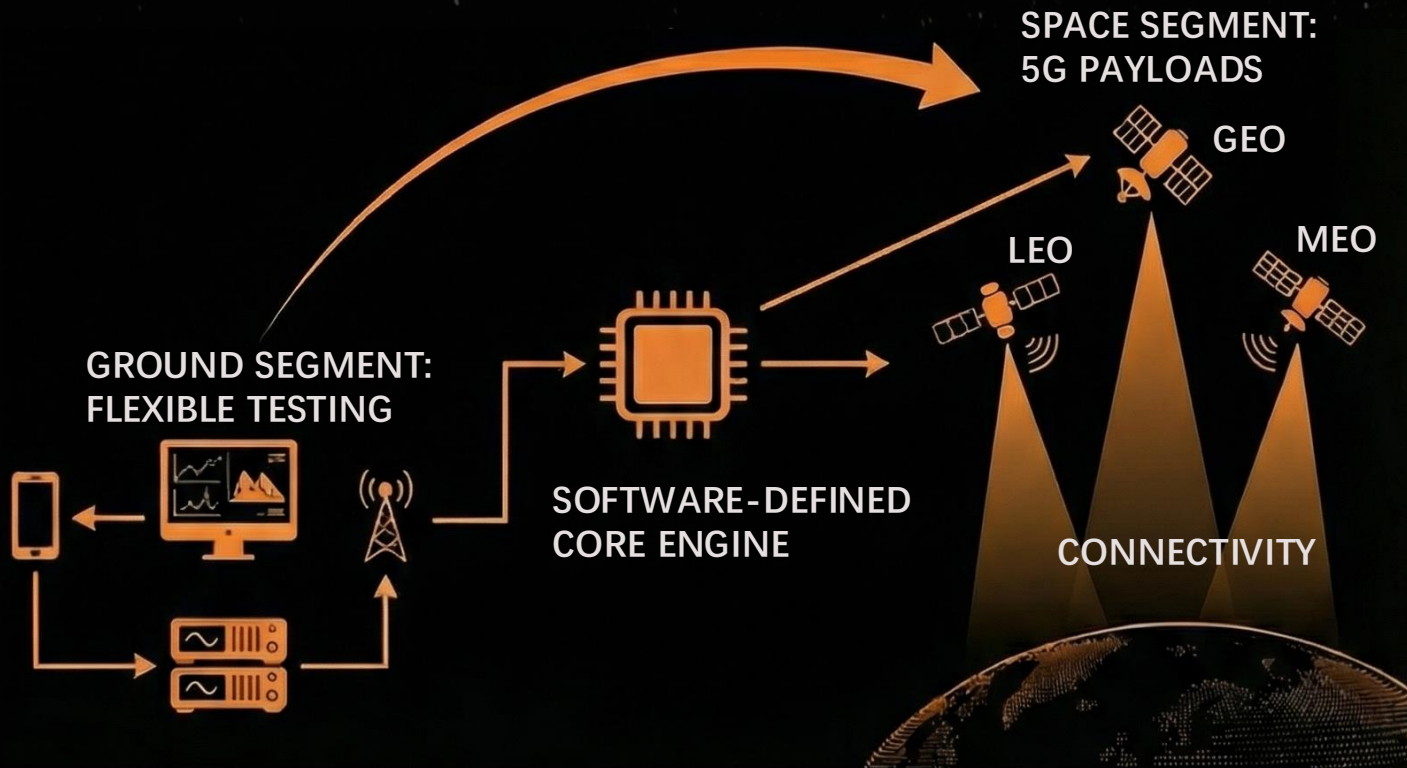
Inspección Segura y Precisa
mediante Inteligencia de Red
Autónoma en 6G



BRAINSTORM



alborspace.com



**BUSINESS
INCUBATION
CENTRE**

Andalusia

albor SPACE

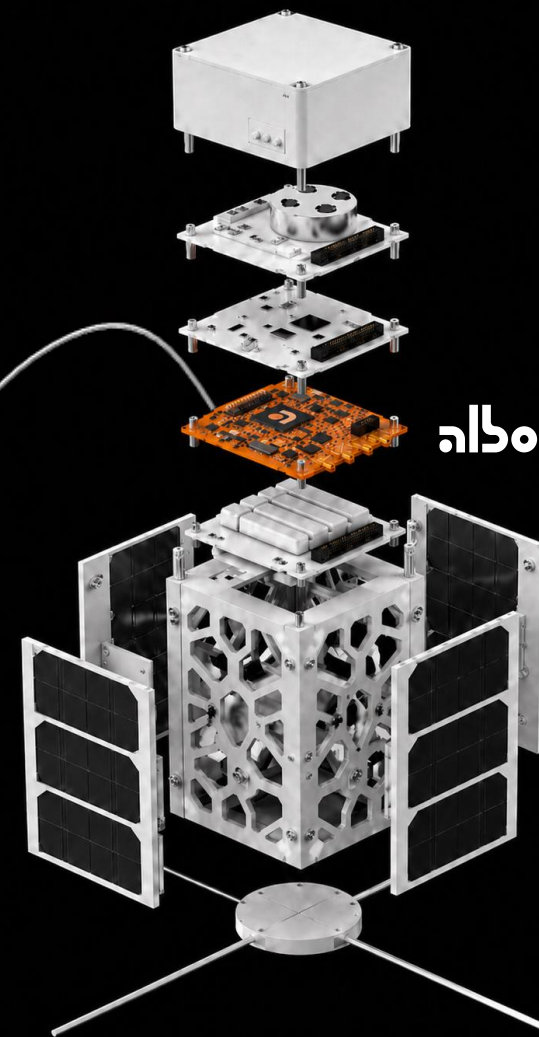


Spin-off award of the University of Málaga
First place in Santander X Awards Málaga
Top 3 Santander X Spain Awards (>1000 participants)

Unleashing the Radio



albor UT



albor RAN

contact@alborspace.com

MÁLAGA SPACE TEAM

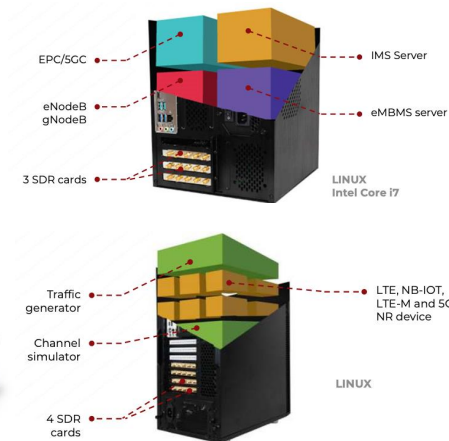
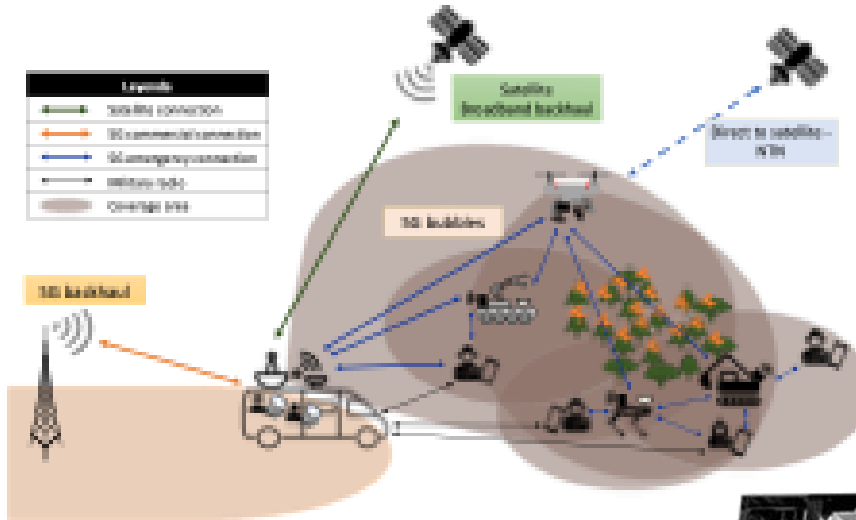
- 40+ students: telecommunications, computer science, industrial engineering...
- CubeSat and ground station.
- Training, e.g. courses with ESA.
- Conferences, congresses, hackathons (Cassini, NASA Space Apps Challenge), etc.
- Communications, platform, ground station, etc.
- Final degree projects
- <https://spaceteam.uma.es/>
- www.linkedin.com/company/malaga-space-team



Infrastructure

...what we have

- > 4 MEur in large testbeds
- 4G, 5G, Open RAN networks
- Emergency deployment and robot nodes
- Testbed and portable equipment
- RICs: Remote Intelligence Controller
- GPUs and Computing
- User applications equipment
 - UEs, CPEs, VR, robots...



...where we are



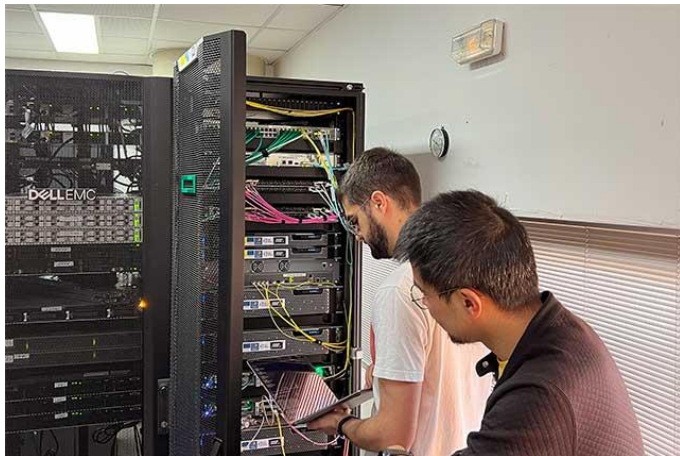
mobilenet HUB

- “Edificio Rosa de Gálvez”, 1st floor
- Large office area
 - 24 desks
 - “Chill area”
- 2 labs
- 1 internal meeting room
- 1 shared meeting room
- Cold room, garden...



mobilenet HUB

- Telecommunication school, 3st floor
- Lab area
 - 12 desks
 - Demos, equipment
- Shared meeting rooms
- Cold room



■ Laboratory and Experimentation Area in New Technologies for Emergency Intervention (LAENTIEC)

- 90 000 m²
- Annual Workshop on Security, Emergencies and Catastrophes



Málaga Satellite Center

- Telecommunication school
- Co-innovation center Vodafone-UMA
- Lab area
 - Faraday cage, large servers, channels emulators...
- Gateway
- Projects development



02 OCT 2025 TECHNOLOGY

Vodafone, AST SpaceMobile and the University of Málaga open the doors to Europe's first space and land-based network lab

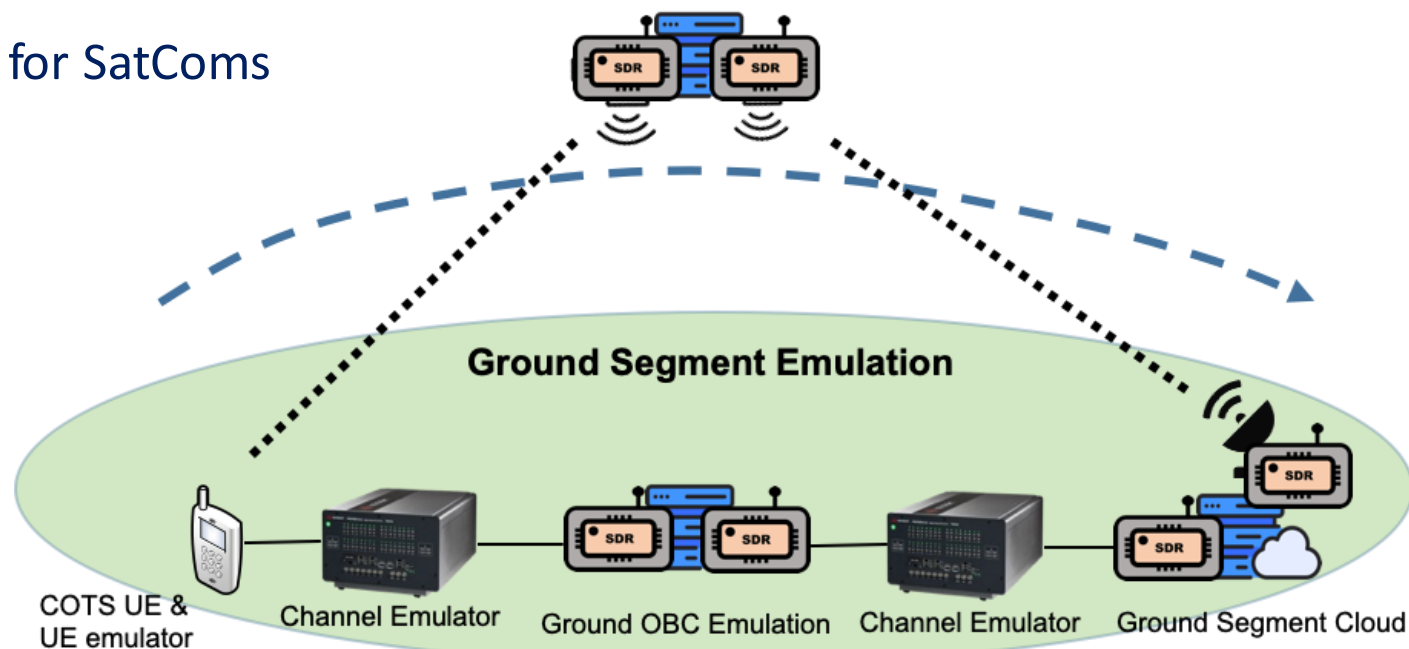
Share

4 minute read



6G-EXPANSE: tEstbed eXtension for PervAsive Non-terreStrial nEtworks

- LEO, 5G/6G, VNF orchestration, channel emulation, constellations, integration with ground.
- +dron, HAPs, GEO..
- x1 5G 8U Cubesat
- x2 Satellite Gateways
- E2E Core & SDR Processing Infrastructure for SatComs



Málaga Satellite Center

- Telecommunication school
- Co-innovation center Vodafone-UMA
- Lab area
 - Faraday cage, large servers, channels emulators...
- Gateway
- Projects development



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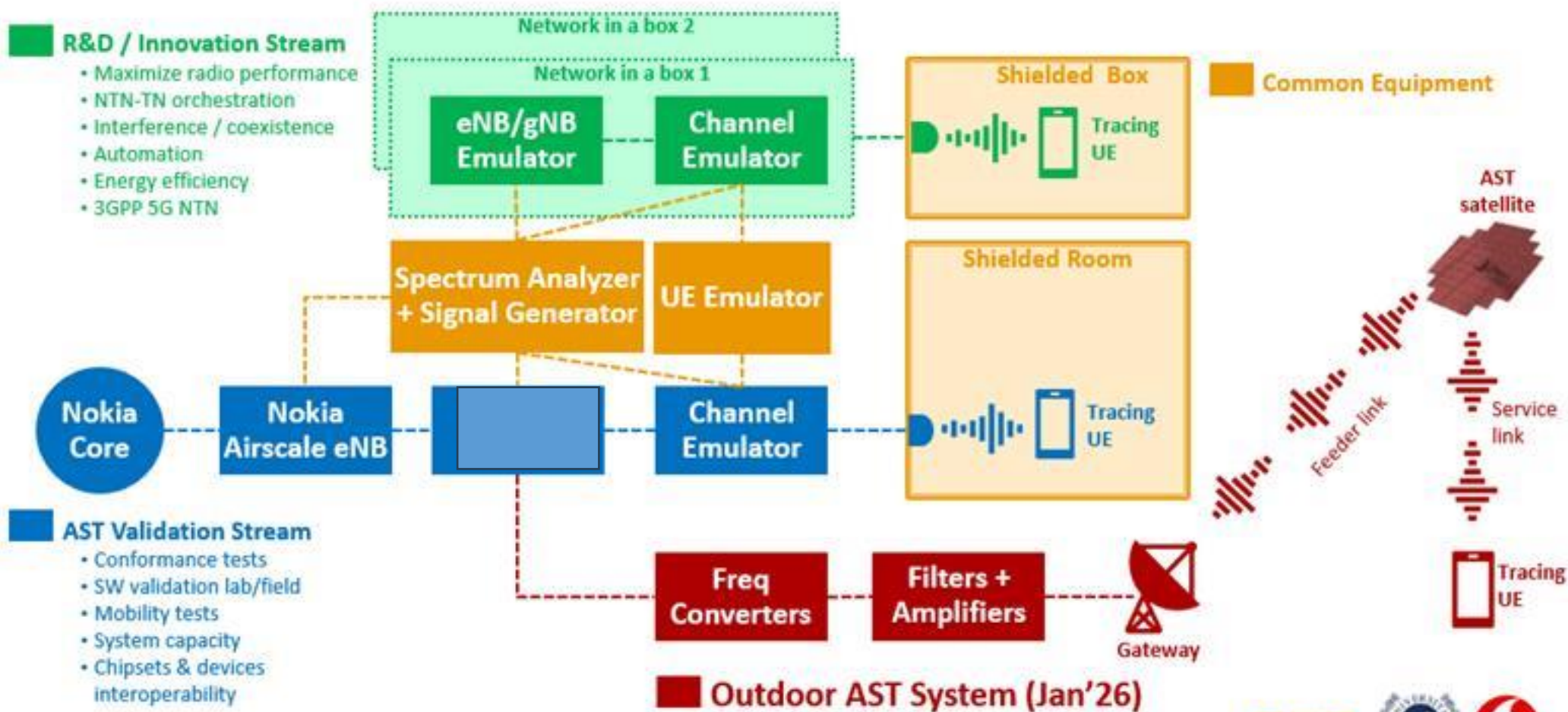


A photograph showing two people working in a laboratory. One person is standing and looking at a piece of equipment, while the other is sitting at a desk. The room has a Faraday cage and various electronic equipment.



Málaga Satellite Center

Málaga Lab brings full E2E satellite network testing



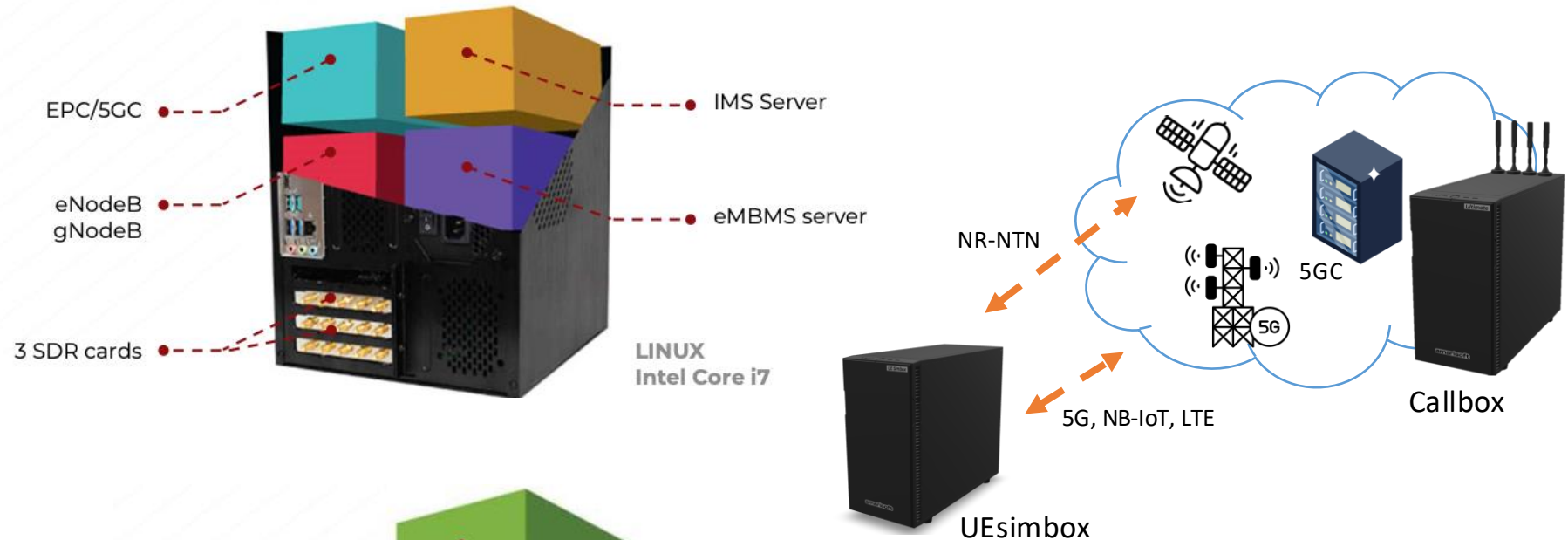
Mobilenet Infrastructure

Network-in-a-box solutions

- 5G, 5G-NTN, NB-IoT and LTE end-to-end programmable testbed solutions.

• Callbox (x2)

- 5G Network in a Box
- Up to 12-cell deployments
- 5G NR-NTN protocol stack
- Channel simulation
- 100 MHz 4x4 MIMO cells
- IMS server, VoNR



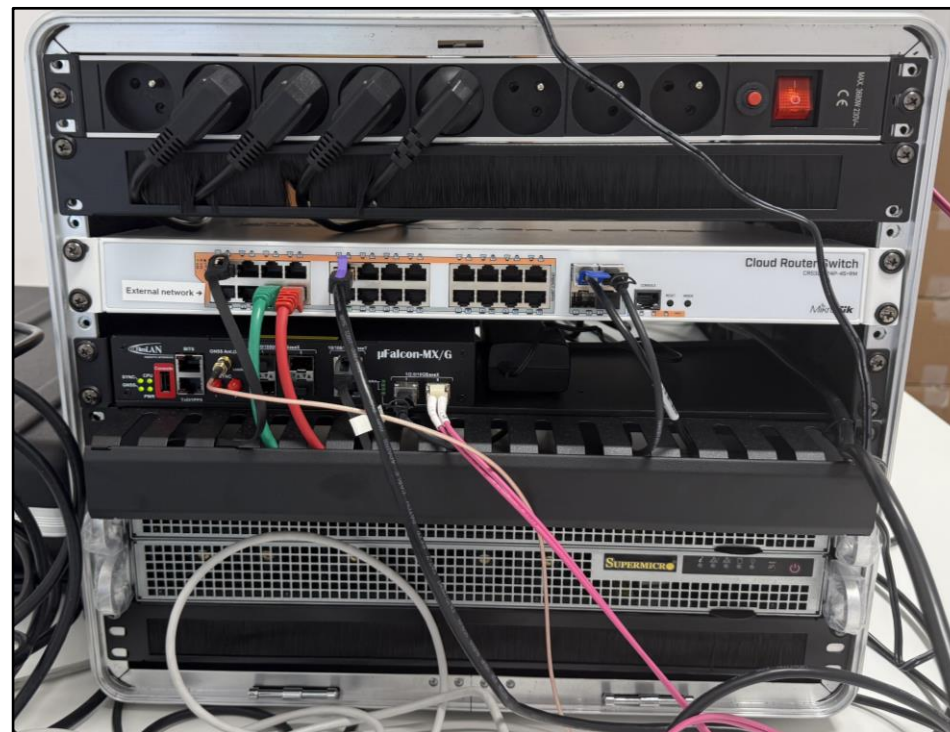
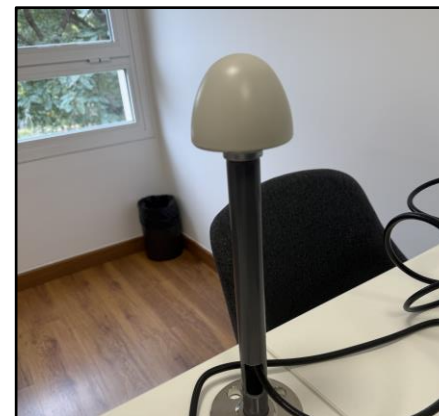
• UEsimbox (x2)

- 5G Multi-UE emulator
- Leading NR-NTN UE on the market
- Up to 64 UEs
- Seamless connection to commercial gNBs
- Channel simulation



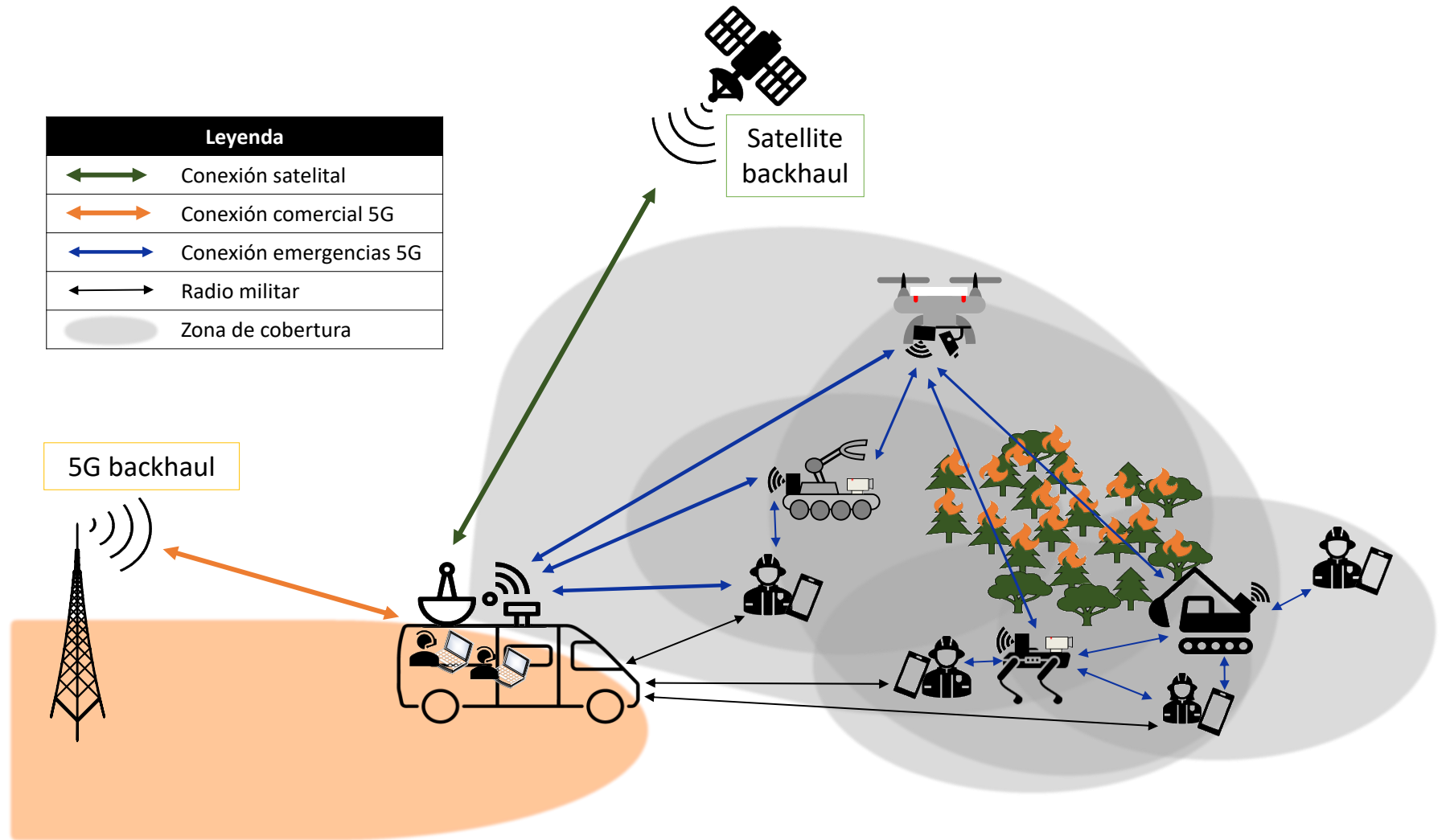
Benetel-SRSRAN Open RAN deployment

- Under the the project MAORI.
- SRSRAN OpenRAN solution covering network core (Open5GS), O-RU, O-CU and O-DU.
- **Complete E2E Open RAN Network -**
- Switch L3
- Switch PTP FibroLAN μ Falcon-MX/G
- Open5GS Core server (+core 2, virtualized and without slicing capabilities)
- srsRAN server (O-CU and O-DU)
- Benetel RAN550 radio unit (O-RU)
- Bullet-type GPS antenna for synchronization tasks.



Emergency

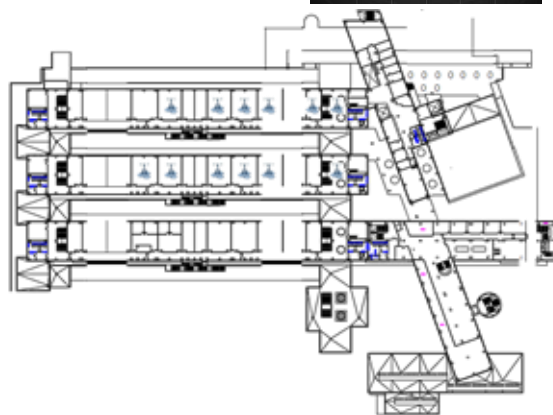
- Equipamiento Científico-Técnico 2024
- “Emergency cloud”
- Robots:
 - Quadruped
 - Wheeled platform
 - Large UAV (>100kg payload)
- Central center Van
- Coms
 - Central portable large 5G network - Van
 - Portable BSs
 - UEs, CPEs



MobileNet Infrastructure

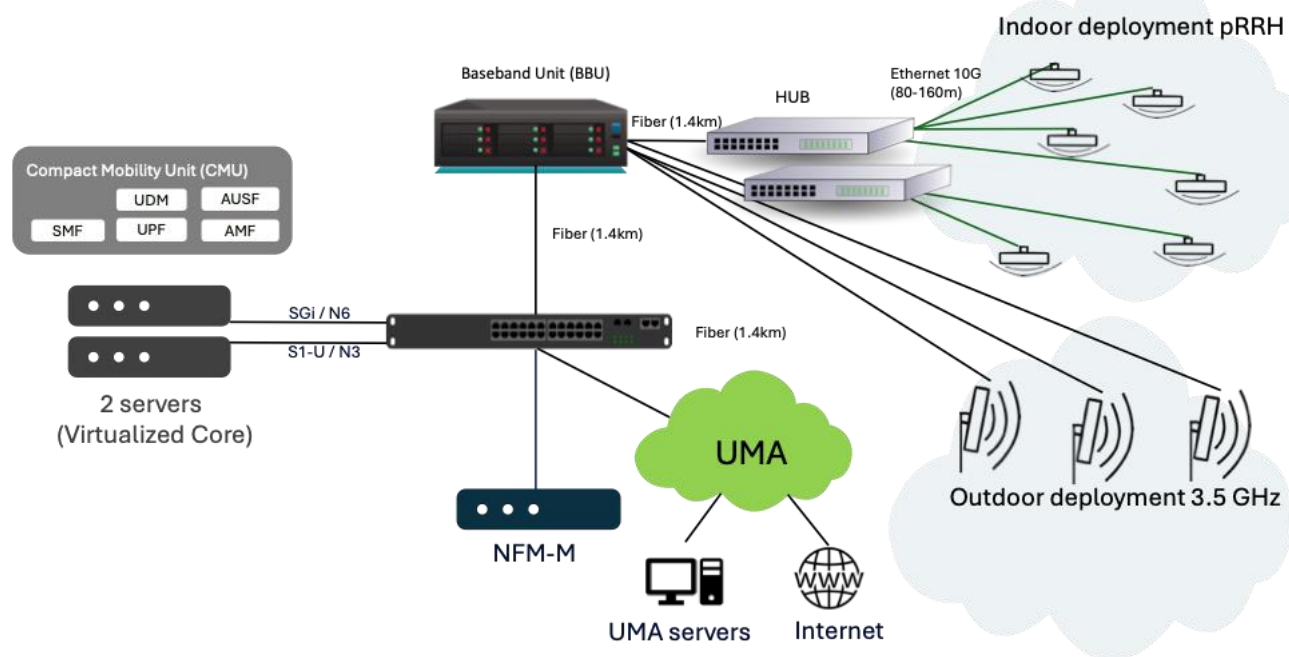
UMAHetNet: LTE/WiFi indoor fully configurable network

- 12-picocells
- eCNS: HSS, MME, S-GW, P-GW...
- Drive test terminals
- Testbed as a service



5G Network

- 3 outdoor beamforming and 6 sub 6GHz (n78, 3.3-3.8 GHz) NR gNodeBs
- SA Virtualized core
- 412,952.39 €



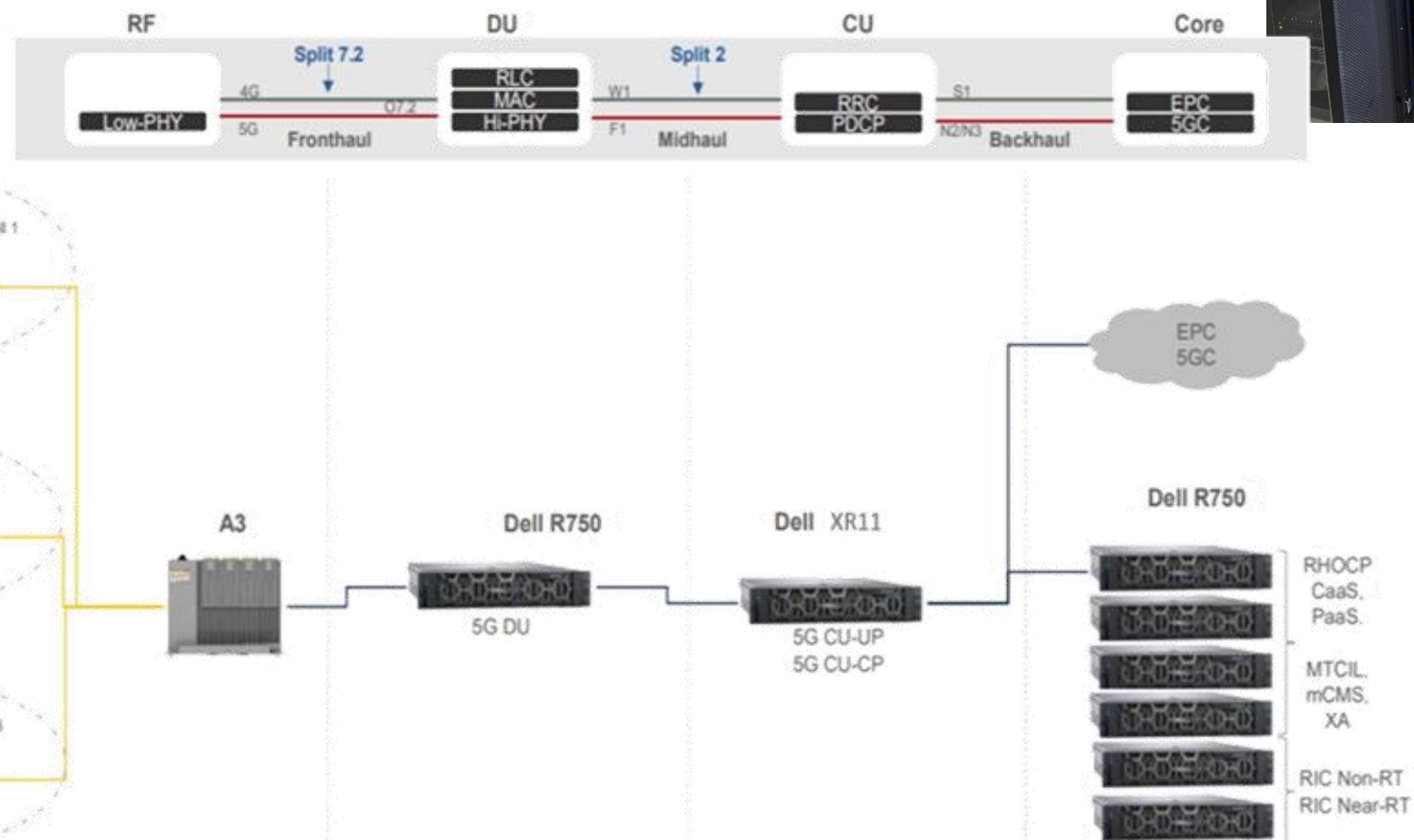
Mobilenet Infrastructure

5G Open RAN Test system

- PANDORA: emulation platform end-to-end radio access - Open and virtualized 5G / 6G core
- 1MEur funding

- **Complete E2E Open RAN Network -**

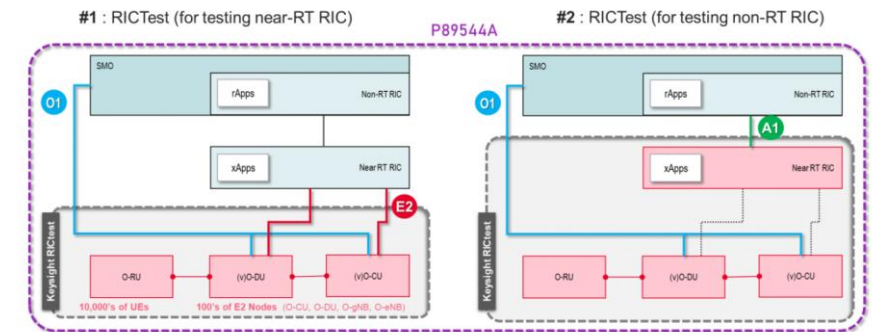
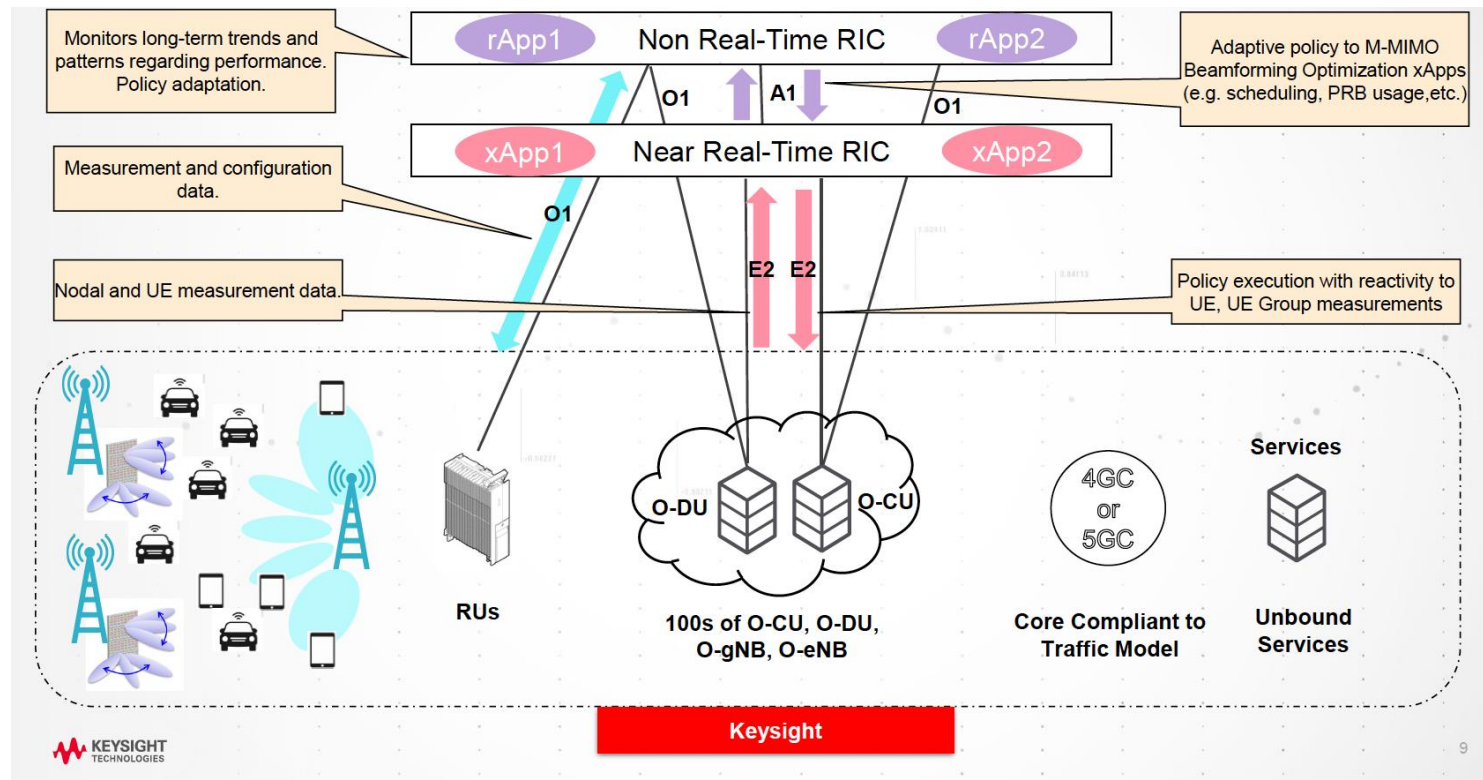
- RU (x5)
 - 3.4 – 3.6 GHz
- RU mmWave (x1)
- DU
- CU
- 5GC
- RIC Non-RT
- RHOC, CaaS, PaaS
- MTCIL, MCMS, XA



Mobilenet Infrastructure

5G Open RAN Test system

- PANDORA: emulation platform end-to-end radio access - Open and virtualized 5G / 6G core
- + Keysight RIC Tester

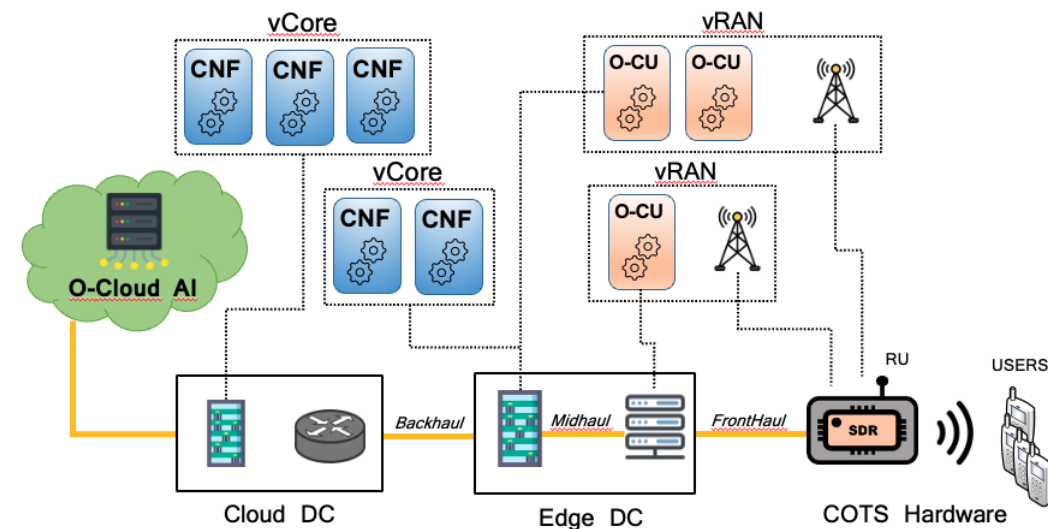


RIC Tester Environment

- Cloud-Native O-RAN Nodes Emulation
- xApps and rApps Testing Platform.

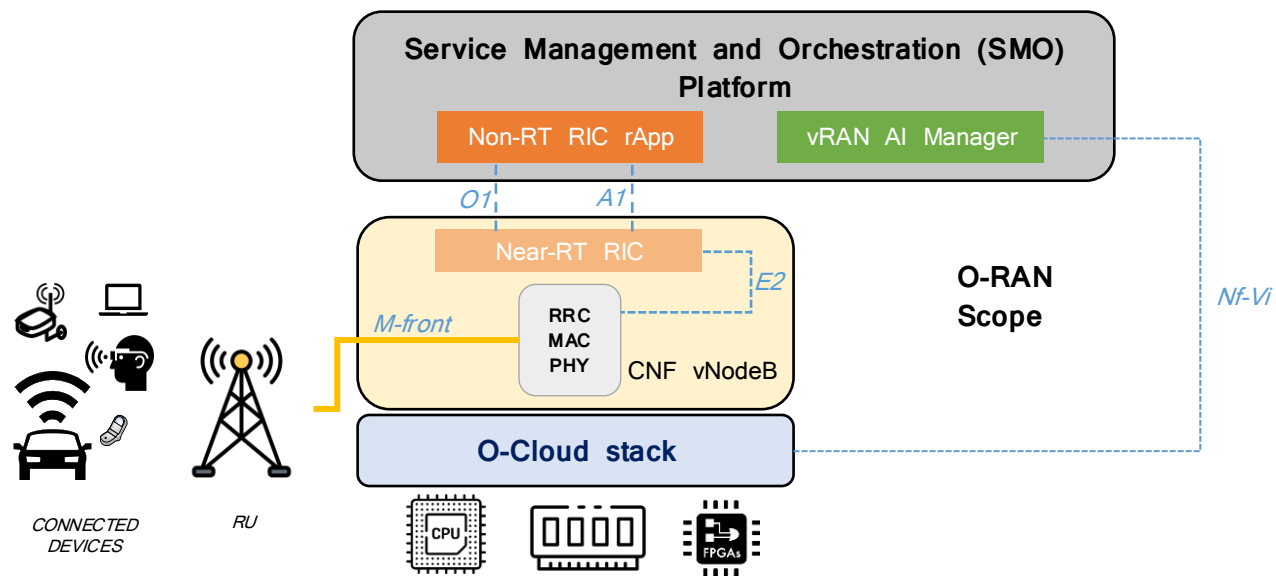
O-Cloud instantiation of vRAN

- Deployed and operational open-source RAN solutions (srsRAN, Open Air Interface) in SDR devices: LimeSDR, USRP N310, B210.
- Connectivity to and evaluation of commercial and testing 5G devices.



Dynamic orchestration and management of vRAN and 5G core

- Online management of computational resources according to RAN needs and for testing.
- Deployed open-source and commercial core distributions: open5gs, srsepc, Amarisoft.
- VNF Kubernetes-based orchestration.
- Noisy neighbors' emulation.
- Satellite deployment.



- **OSC NearRT-RIC + OSC NonRT-RIC + Open5GS + srsRAN + Amarisoft's UESimbox**

- **Integrated O-RAN Testing Platform:**

- xApp and rApp testing

- **Support for NTN deployments.**

- **Emulation of up to 64 UEs simultaneously.**

- **Standards Compliance:**

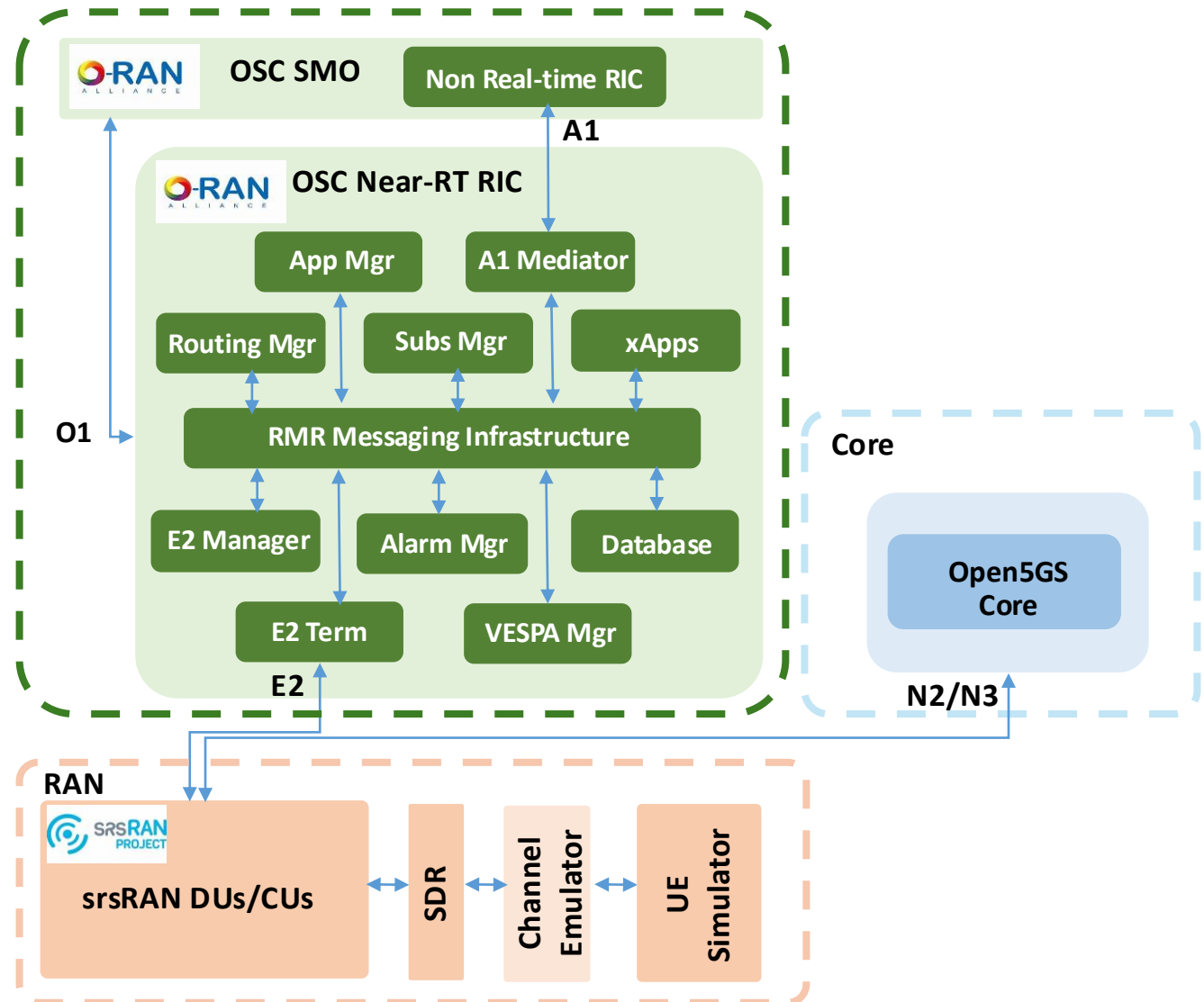
- Standard A1 and E2 interfaces.
- 3GPP-compliant N2 and N3 interfaces.

- **Non-RT RIC policy testing.**

- **E2SM_RC Control Service Style 2 supported.**

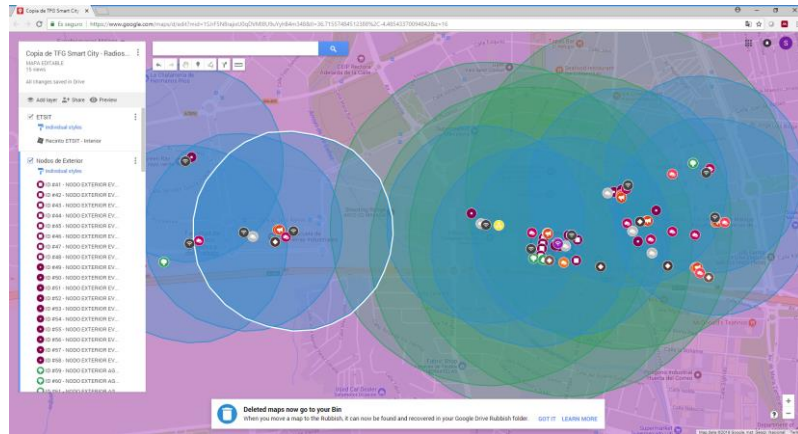
- **E2SM_KPM Report Service Styles (1 - 5) Supported:**

- 6 ORAN metrics available: DL / UL throughput, UL packet success rate, RLC DL packet drop rate, RLC DL / RLC UL transmitted SDU volume.



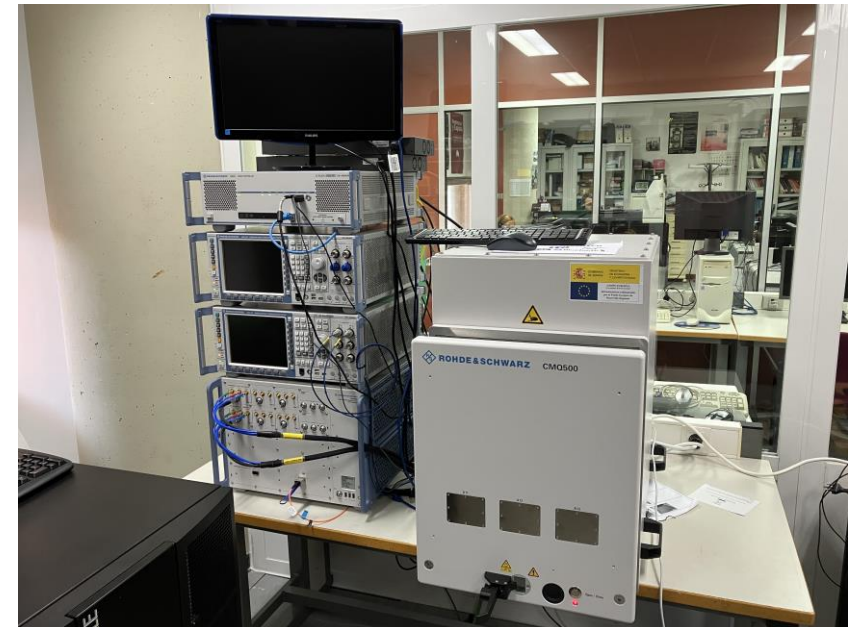
UMA IoT/RAT

- 120 IoT nodes
- Multi-RAT: WiFi, LoRa, Sigfox, Zigbee, LTE...
- Fully configurable network and IoT database framework.
- LoRa Gateway
- Fiware platform



UMA RADIO TEST SYSTEM

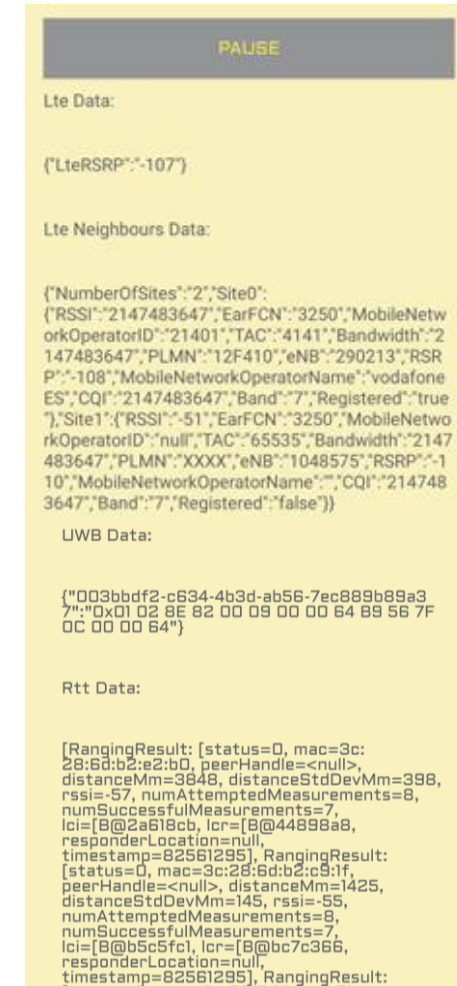
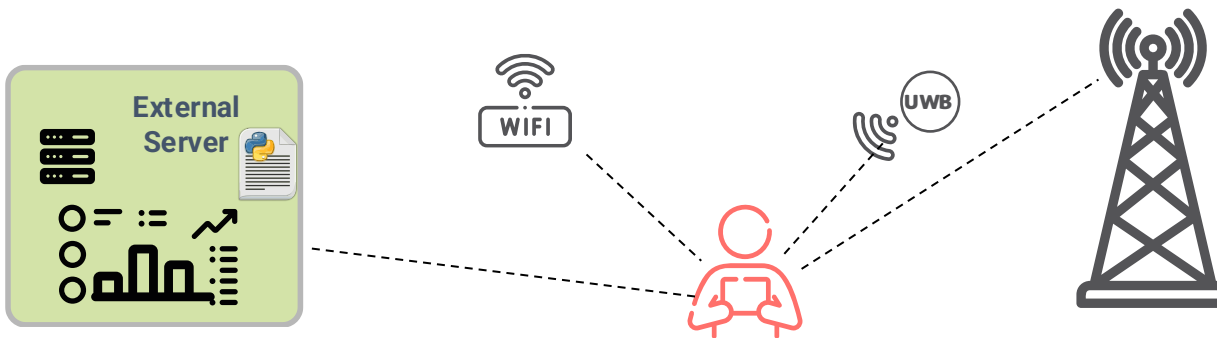
- 5G/WLAN Testing and emulation testbed
- R&S CMW500 wideband radio communication tester
- R&SCMX500 5G one-box signaling tester
- Tester of 5G NR in FR1 and FR2
- Up to 2 gNB + 1 LTE eNB + 1UE
- Small Anecoic Chamber



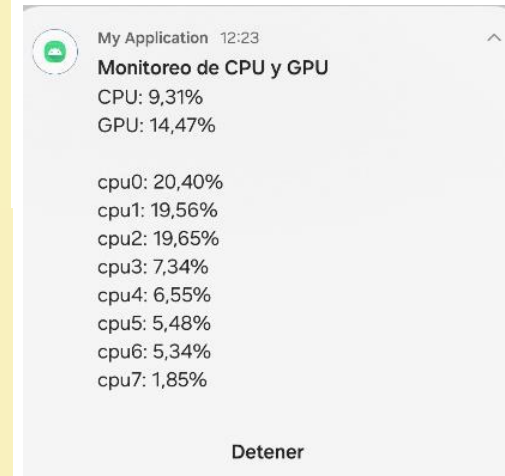
Mobilenet Infrastructure

- **Monitoring Android App:**

- LTE – RSRP, RSRQ, etc. from serving and neighbour cells
- 5G – RSRP, RSRQ, etc. from only serving cell
- WiFi – RSSI, Time of Flight (ToF), channel, etc... from different APs
- UWB – ToF from different APs
- Bluetooth – RSSI
- CPU and GPU performance metric for energy consumption
- Refresh rate for most KPIs <1s
- Developed in Kotlin (mostly) and Java
- All this information is sent to an **external server** via HTTP / Flask to process the information for SON, localization, energy metering, etc.
- Information is stored in MySQL and shown in Grafana for post-processing



Signal Processing

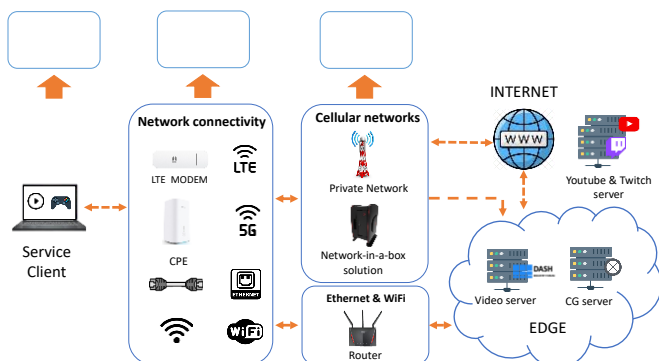


Hardware measuring

MobileNet Infrastructure

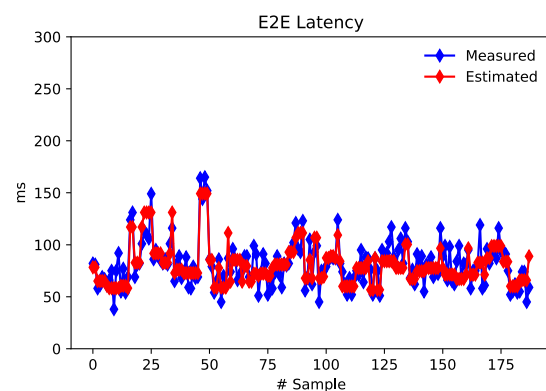
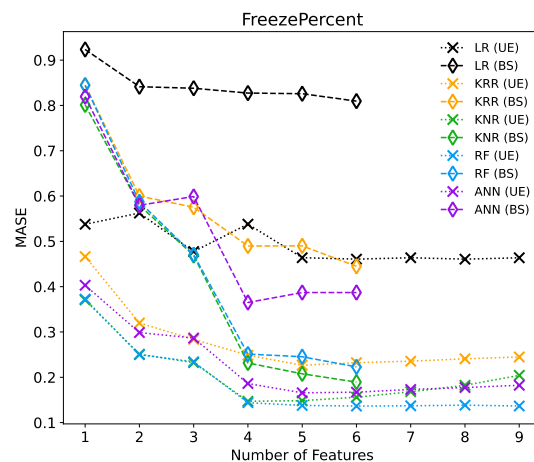
Service monitoring

- Measuring E2E metrics related to QoE of the service
 - Video Streaming
 - Video 360/VR
 - Cloud Gaming
- Continuous fully-automated measurement campaign



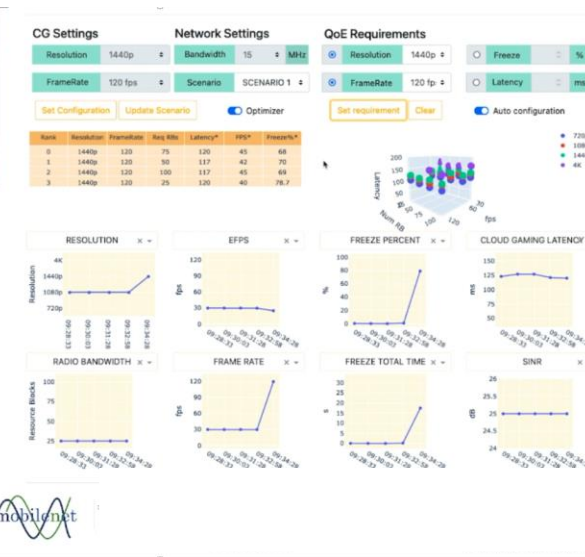
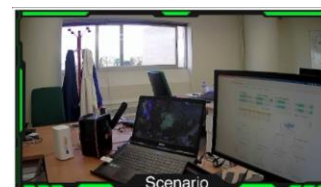
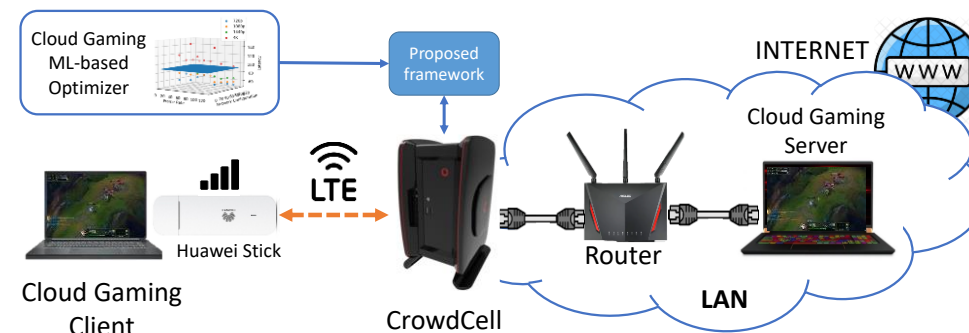
KQI estimation

- ML models for estimating E2E metrics from network KPI & configurations.



Network optimization based on KQI metrics

- Fully integration of ML models with network management.
- Tuning configuration parameters for boosting service provision.



Mobilenet Infrastructure

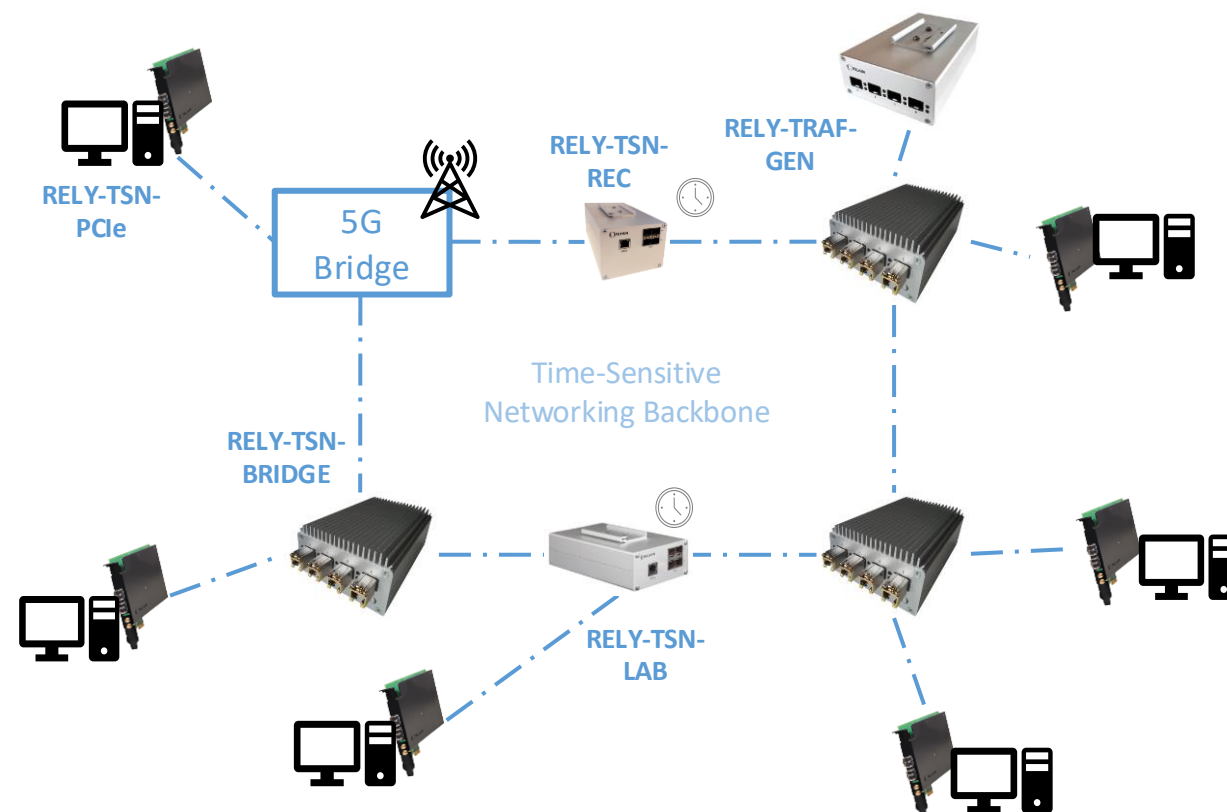
TSN+ETH+5G end-to-end testbed for deterministic traffic characterization and development of innovative time sensitive applications in mixed criticality domains (aerospace, industry, automotive...)

- Testing tools for recording, error injection, hardware timestamping, etc.
- Supported standards: IEEE 802.1AS, 802.1Qbv, 802.1Qav, 802.1Qcc, 802.1Qbu, 802.1CB, 802.1w, 802.1AB, 802.1Qci

Elements:

- **6x RELY-TSN-PCIE:** *Time-Sensitive Networking Bridge PCIe NIC*
- **2x RELY-TSN4:** *4 port Time-Sensitive Networking Switch*
- **1x RELY-10TSN12:** *8 copper ports 1G + 4 SFP ports 10G Time-Sensitive Networking Switch*
- **1x RELY-TSN-LAB:** *Time-Sensitive Networking Testing Tool*
- **1x RELY-TSN-REC:** *Time-Sensitive Networking Traffic Recorder*
- **1x RELY-TRAF-GEN:** *Traffic Generator*

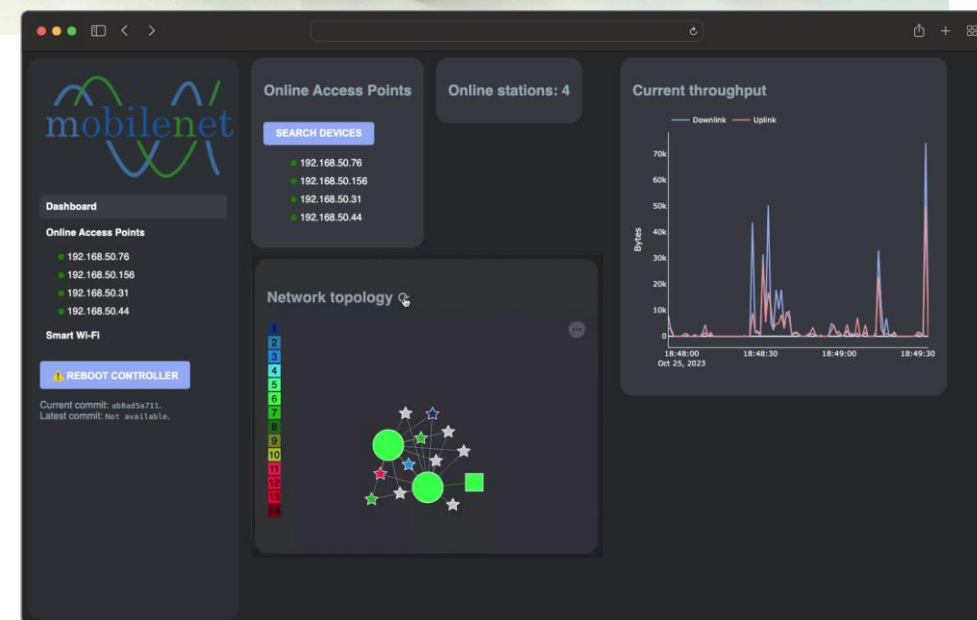
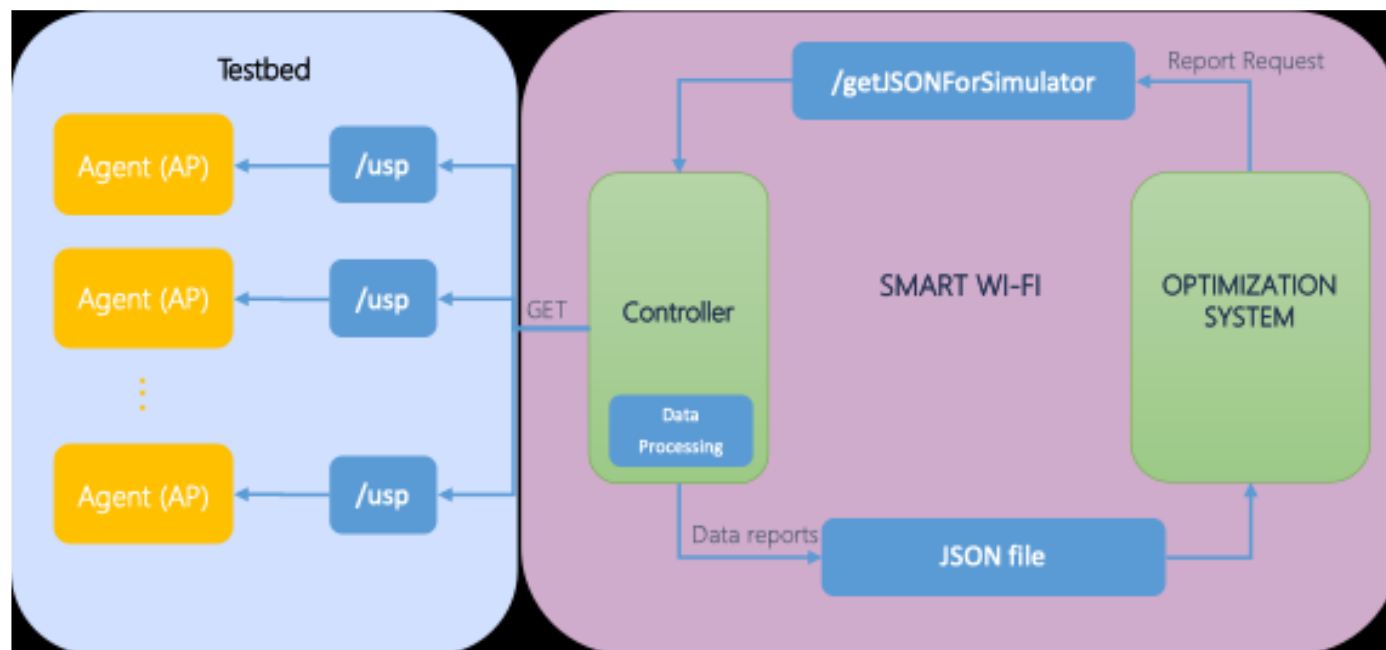
Test automation



Mobilenet Infrastructure

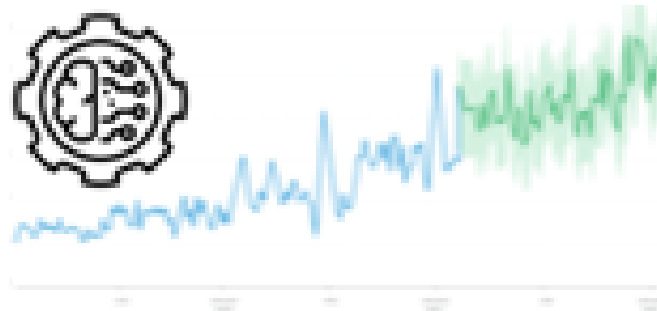
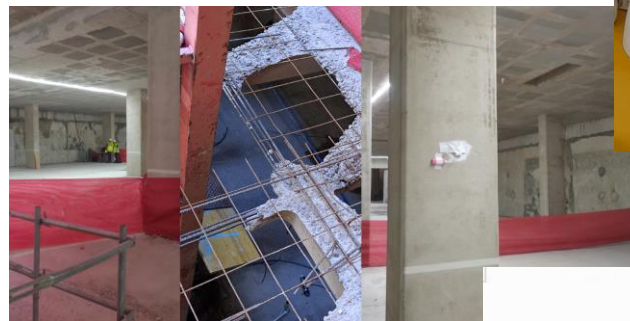
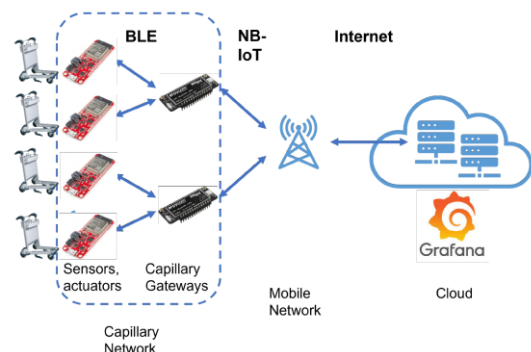
Wi-Fi Testbed

- 6x controllable APs
- Service-layer metrics capture
- Close loop optimization
- API



SENSING

- UMA IoT/RAT – 120 IoT Nodes network
- Custom-made MOBILENET developed sensors for:
 - Green house gasses emissions
 - Presence,
 - Weather
 - Environmental luminosity, presence...
 - Luggage trolleys occupancy and movement
 - Construction-sites
 - Sport-tracking
 - UWB-based, BLE-based localization
 - Drive testing
 - Fleet tracking
- Integrated coms: BLE, NB-IoT, UWB, LTE, 5G...
- Data acquisition and representation
- Advanced data processing: Data completion, forecasting, optimization, failure management



Robotic platforms

- Tools for mobile 5G deployment, cloud robotics, rescue/defense applications, drive testing, video capture and streaming, mapping...
- Multiple elements available: ground robots, UAVs, robotic arm...
- Some key elements:
 - **UNITREE ROBOT Go1 EDU**
 - 4G / 5G, WiFi connectivity
 - Speed: 0~3,7 m/s
 - LIDAR 2D / 3D
 - 5 Cameras
 - 12 kg
 - Payload: 5 kg
 - **Robot arm Tinkerkit Braccio**
 - 4G / 5G, WiFi connectivity
 - 5DoF
 - <800g of weight
 - **UAV Hexsoon EDU 450 quadcopter:**
 - 4G / 5G, WiFi connectivity
 - GNSS RTK
 - Up to 400g of payload
 - Open-source autopilot system



Companies involved in our infrastructure

- Verticals, telecommunication manufacturers, telecom consultancies, SMEs...

_VOIS



Telefonica



NOKIA

SAMSUNG



AERTEC

AIRBUS



Mobilenet Infrastructure

Proof of concepts

- Implementation and tests using UMA infrastructure.
- Joint and standalone PoCs.
- Trials and demonstrations.



FEINDEF 2023, 2025



MWC 2019
MWC2023, 2024, 2025, 2026
(O-RAN Alliance)



One5G Intermediate Rev., Brussels 2018



EuCNC 2018



Best Booth Award

ONE5G –
E2E-aware Optimizations and
advancements for Network Edge
of 5G New Radio

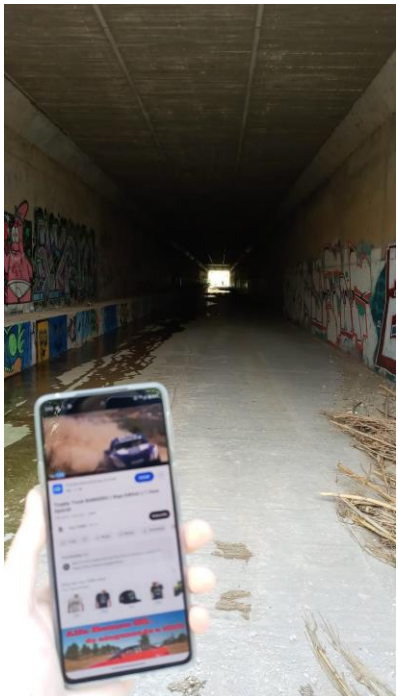


EuCNC 2022...

MobileNet Infrastructure

Proof of concepts

- Emergency response days :
 - <https://www.uma.es/sala-de-prensa/noticias/xvii-jornadas-internacionales-de-la-uma-sobre-seguridad-emergencias-y-catastrofes/>
 - Deployment of ad-hoc private cellular networks for rescue and defense applications
 - Victims' localization: BLE, WiFi. 5G...



MobileNet Infrastructure



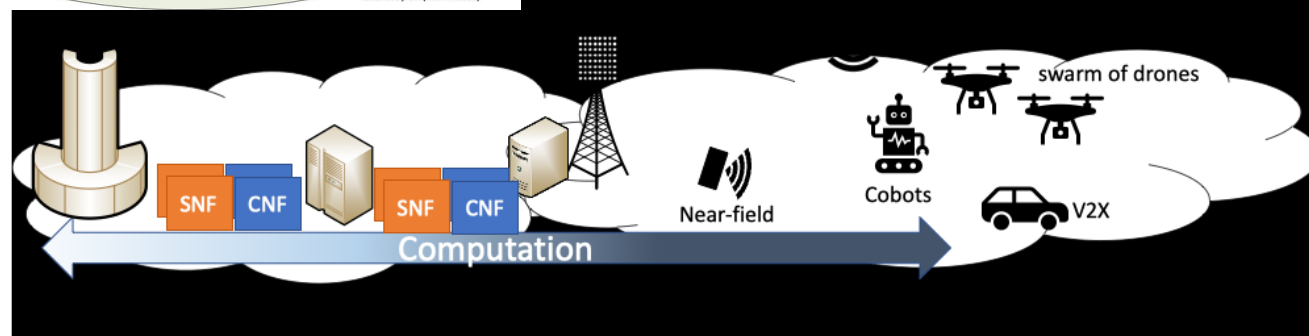
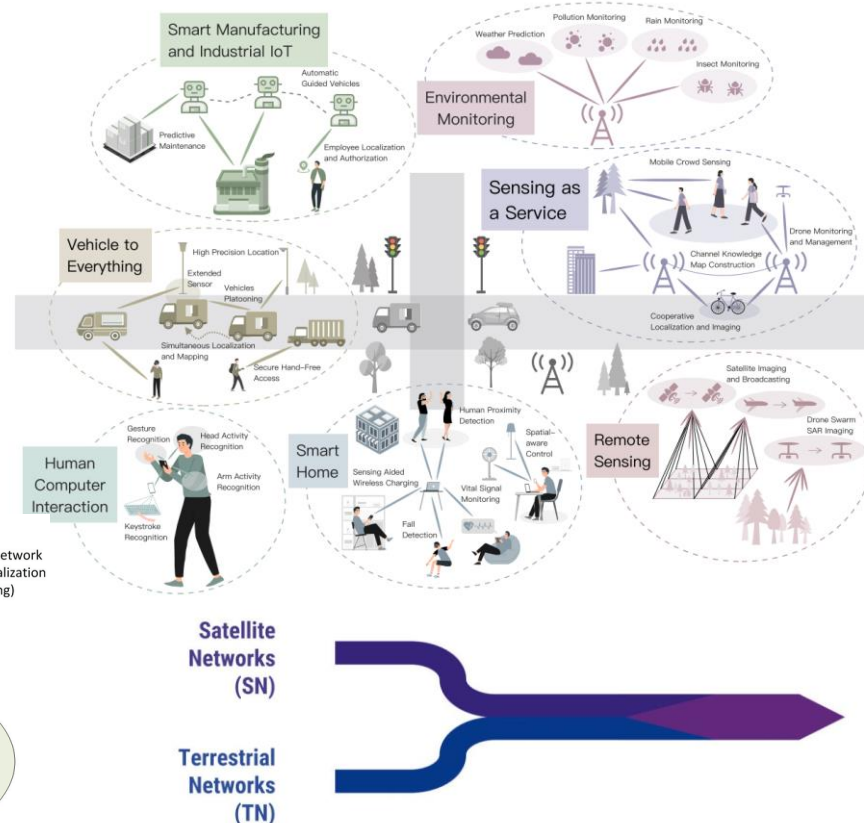
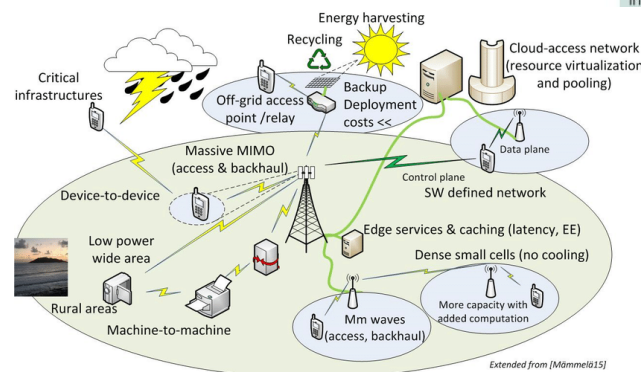
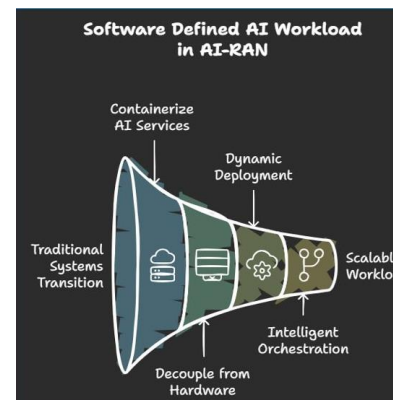
MobileNet Infrastructure





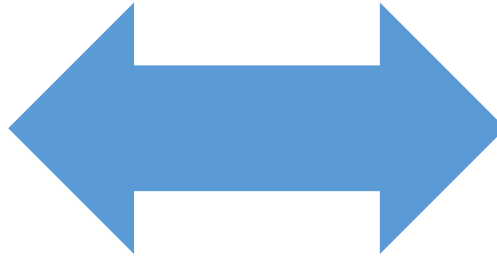
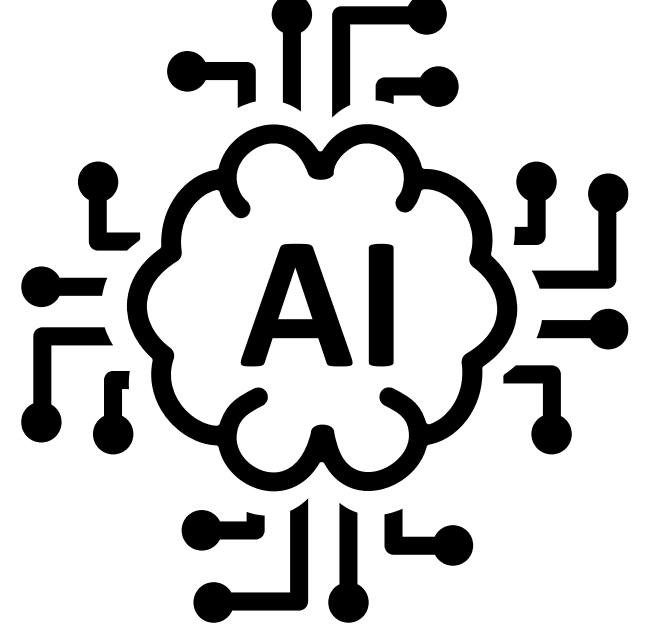
5G/6G Key Areas of R&D

- AI-based management / Zero Touch Networks
 - LLMs / multi-modal, Quantum-ML, Intent-based management, conflict resolution, Open RAN schemes (moving towards real-time), ML life-cycle...
- Virtualization / orchestration (both VNFs and services) management
- TN/NTN integration, orchestration, mobility...
- JSAC orchestration
- Security: PHYSEC, CYBERSEC – especially with ML application / focus
- Energy-saving
- Network-supported AI
- Network-supported services / use cases
- Critical Communications



Experiences with testbed-as-a-service

Networks



We need data! Verticals, use cases,
reproducible, accessible...

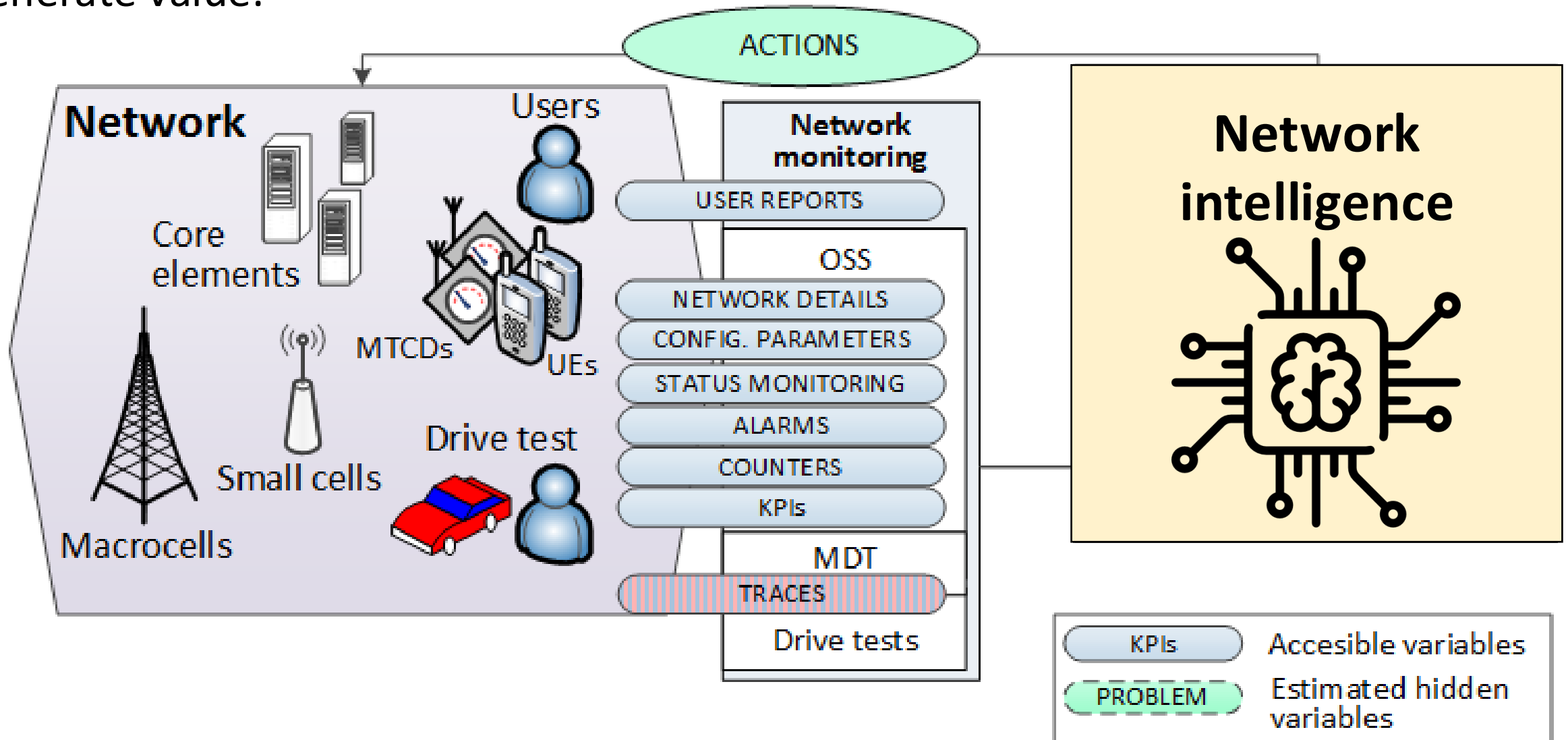


AI to the rescue of the Network



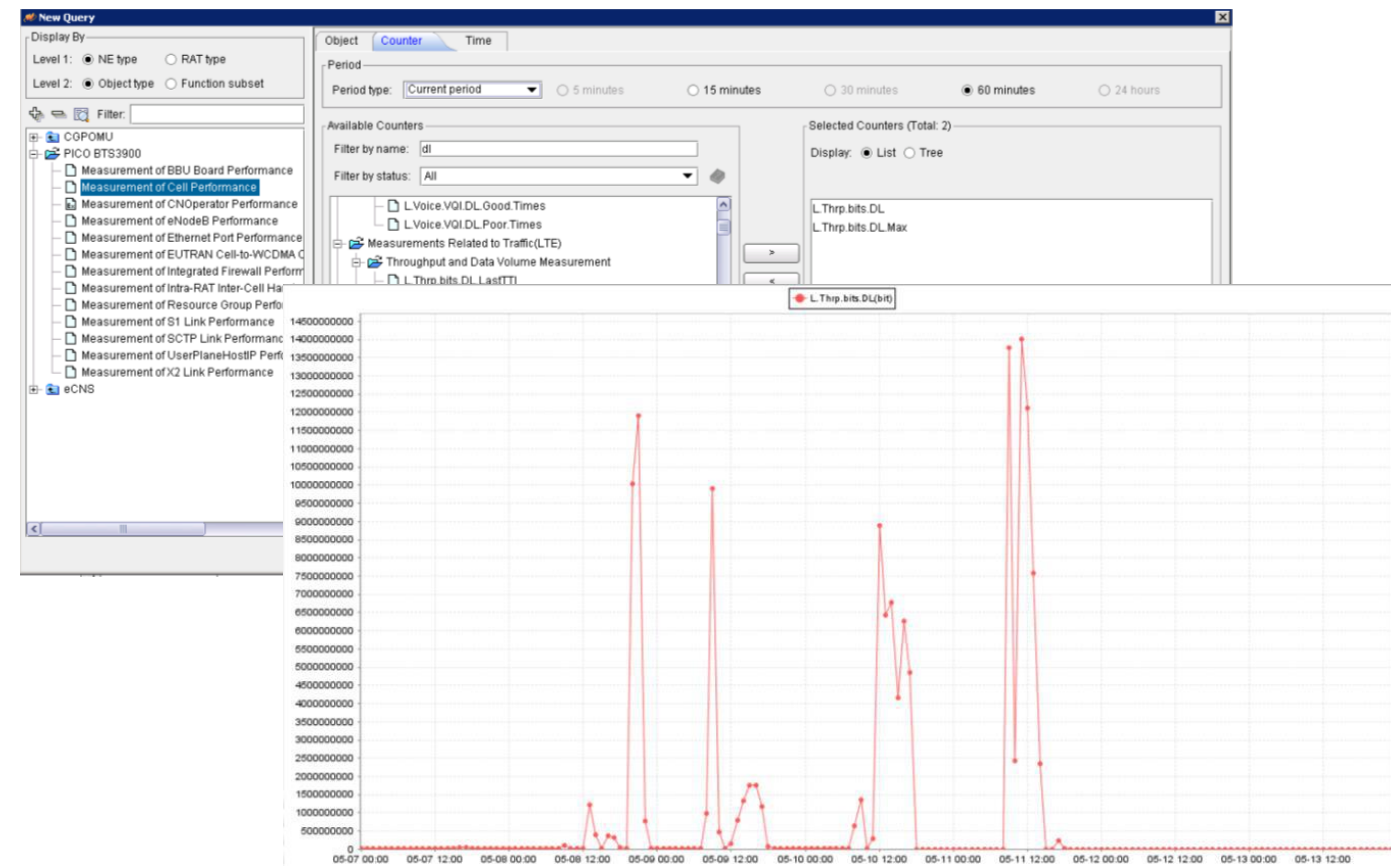
AI to the rescue of the Network

Networks generate a huge amount of data to process, understand, take action and generate value.



Sources

- **Commercial OSS – centralized management**
 - Databases, APIs, config. files...
 - Typical data: config, monitoring, alarms, events, traces...
- **Softwerized + SDR-based solutions - OCUDU / OAI platforms**
 - Console traces, Logs, APIs, PCAPs...
- **Commercial UEs**
 - Android / Apple apps – limited, dependent on the terminal model...
- **Drive-test terminals**
 - Nemo, Qualipoc
 - PCAP, geolocalized logs
- **Modems, CPE**
 - API, AT commands
 - Quectel...
- **Traffic analyzers, sniffers...**
- **End clients / servers**



2 main parts:

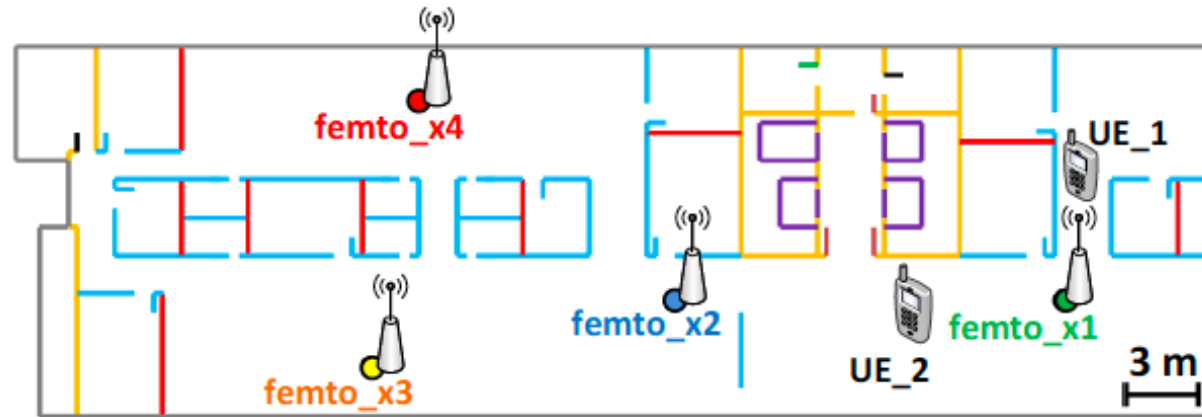
- Measure
- Configure

Evolution:

- Matlab GUIs (yes Matlab!), java sockets, logs (shared folder, dropbox!)
- Teamviewer, remote desktop
- Grafana
- Web interfaces
- Selenium, web scrapping...
- APIs
- Kubernetes, docker...

■ Real femtocell office environment

- ❑ 55x25 meters.
- ❑ 4 UMTS femtocells - Alcatel-Lucent **9365** Base Station Router Femto.
- ❑ Multiple terminals.
- ❑ App Android for RSCP values reporting.



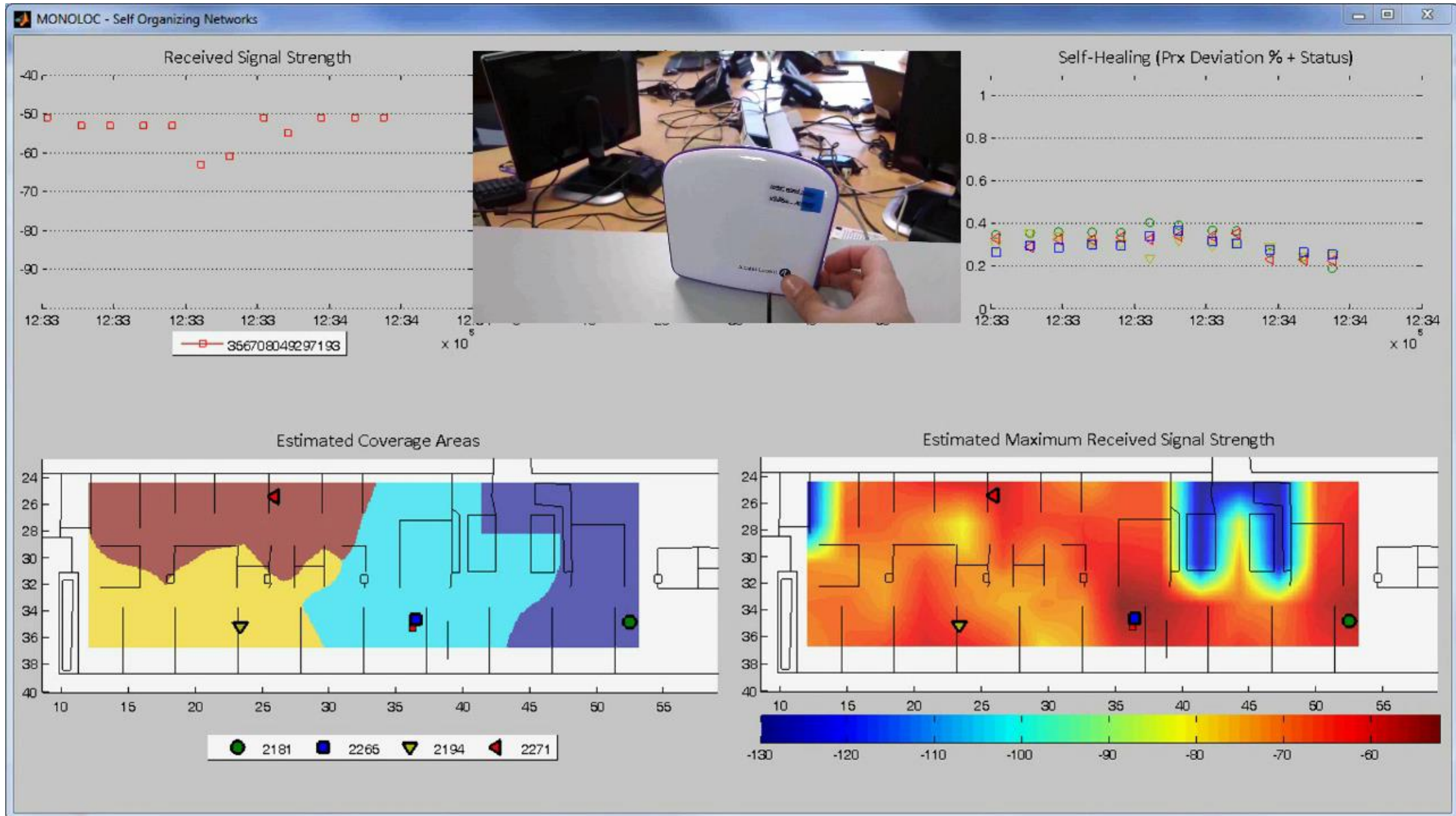
— External Wall: Glass + Brick	— Doors: Wood
— Internal Wall: Glass	— Doors: Glass
— Internal Wall: Wood	— Doors: Metal
— Internal Wall: Brick	— Doors: Metal + Wood
— Internal Wall: Elevator	— Doors: Elevator

S. Fortes, A. Aguilar-García, R. Barco, F. B. Barba, J. A. Fernández-luque and A. Fernández-Durán, "Management architecture for location-aware self-organizing LTE/LTE-a small cell networks," in IEEE Communications Magazine, vol. 53, no. 1, pp. 294-302, January 2015

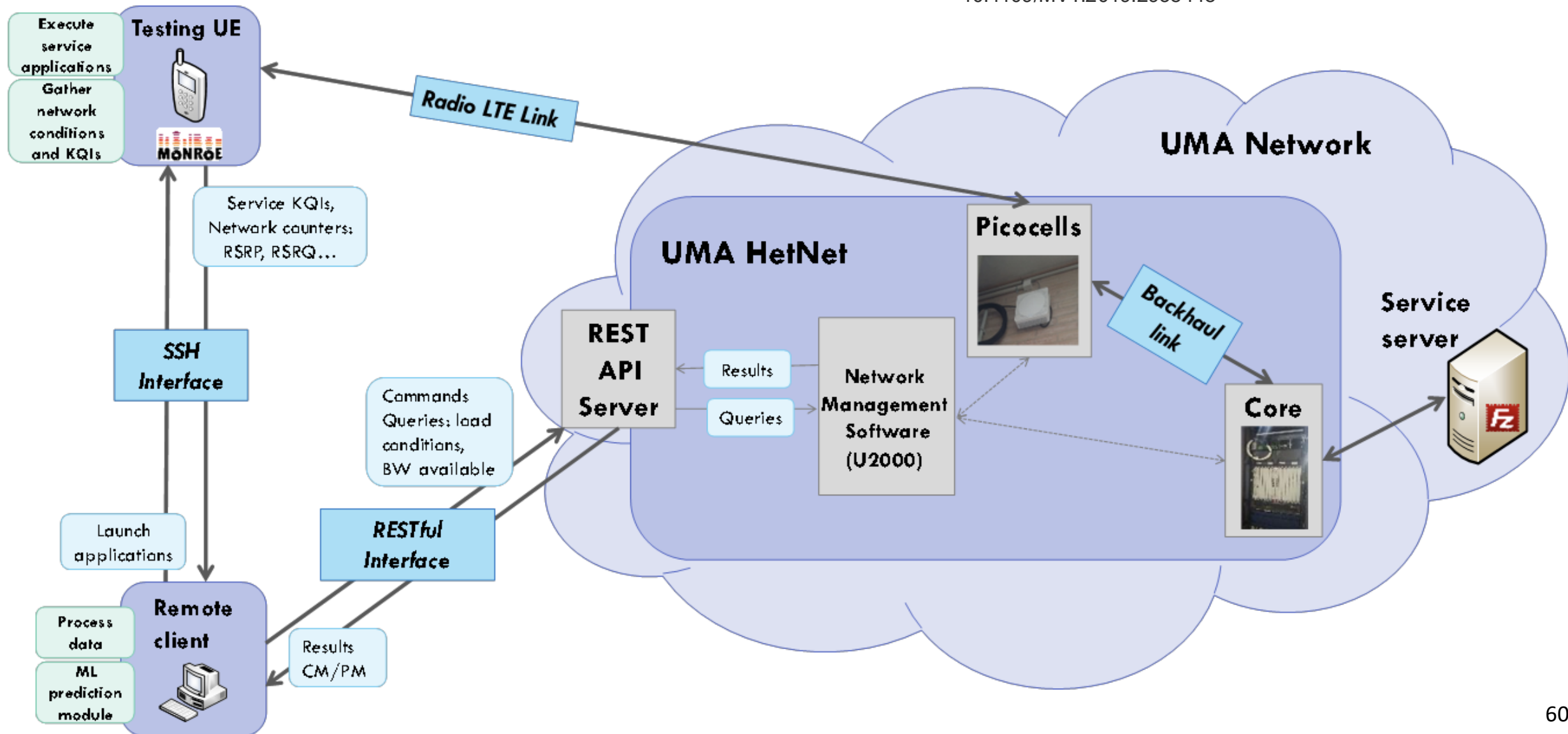
A. Aguilar-Garcia et al., "Location-aware self-organizing methods in femtocell networks", Computer Networks, vol 93, bll 125–140, 2015.

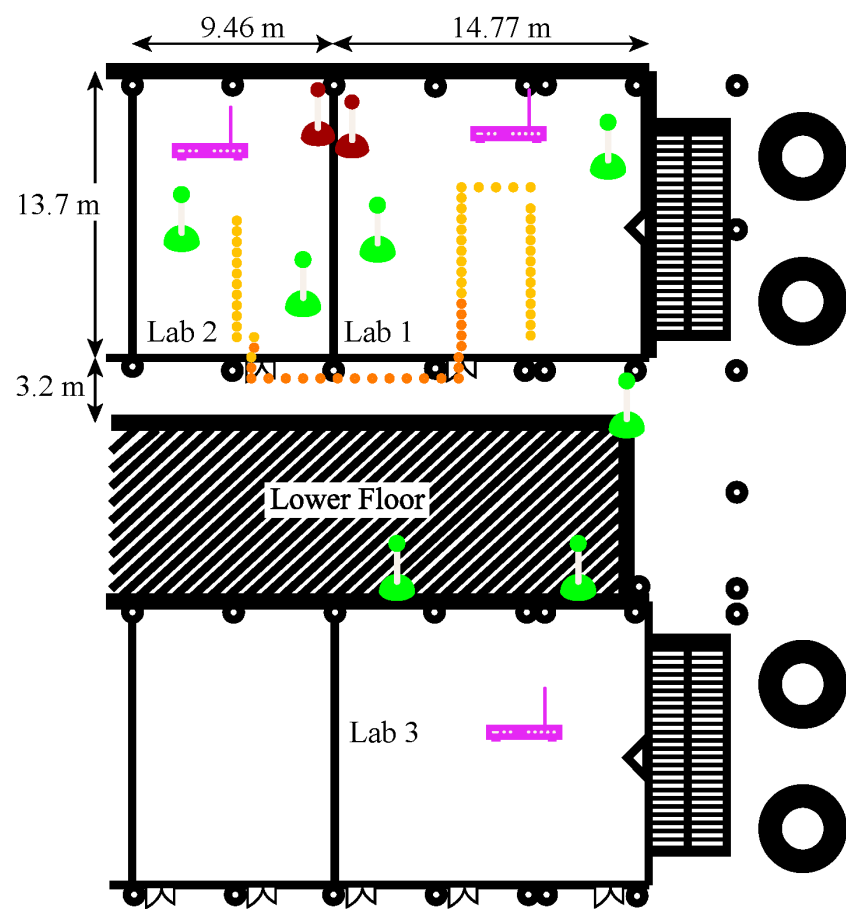


- Matlab interfaces – Melodic

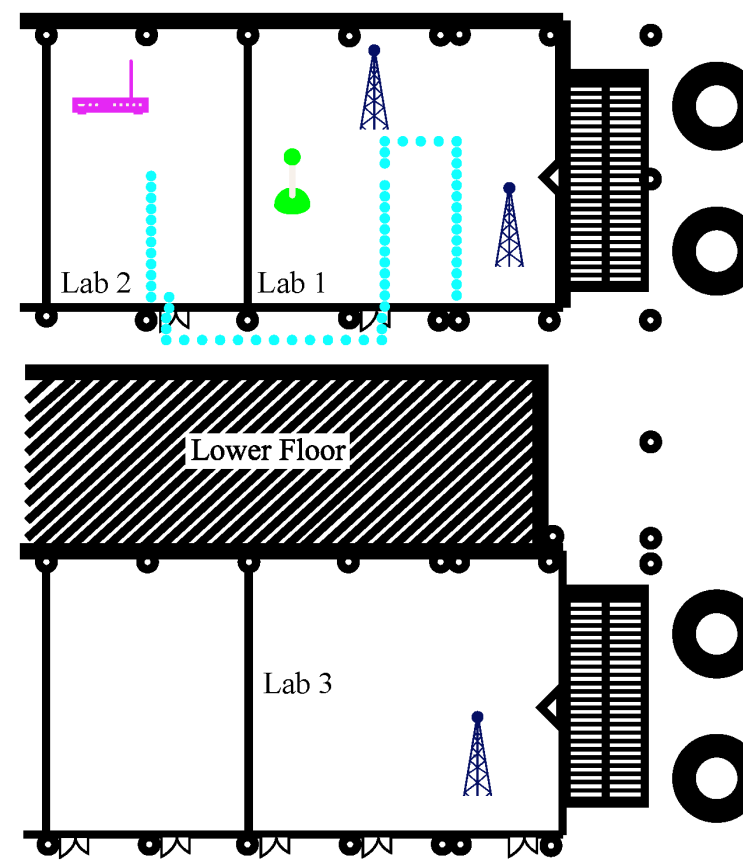


A. Herrera-Garcia, S. Fortes, E. Baena, J. Mendoza, C. Baena and R. Barco, "Modeling of Key Quality Indicators for End-to-End Network Management: Preparing for 5G," in *IEEE Vehicular Technology Magazine*, vol. 14, no. 4, pp. 76-84, Dec. 2019, doi: 10.1109/MVT.2019.2938448

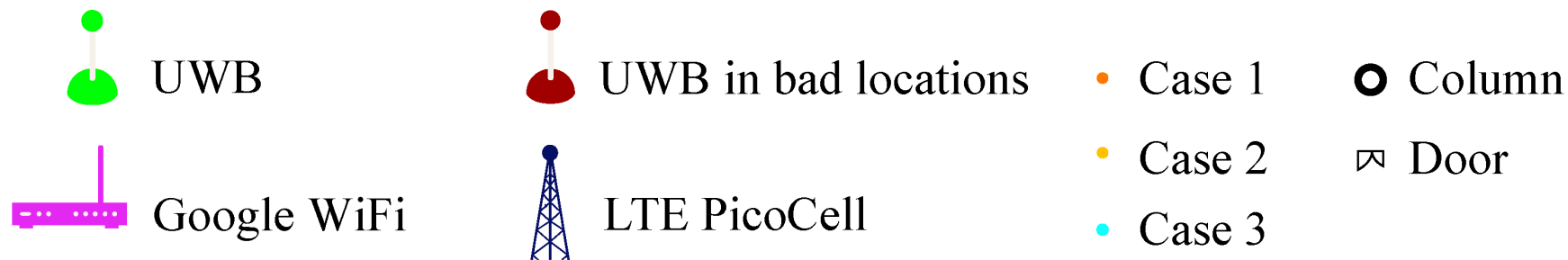




Scenario a)



Scenario b)



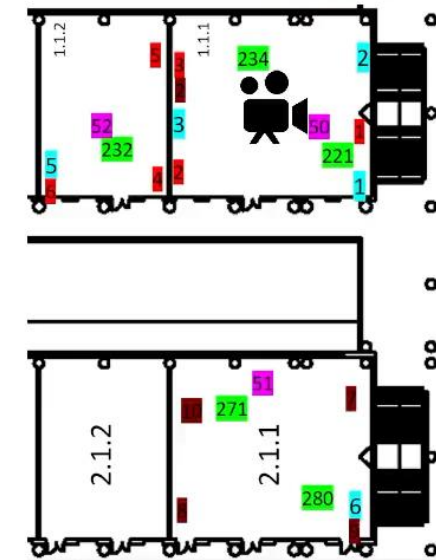
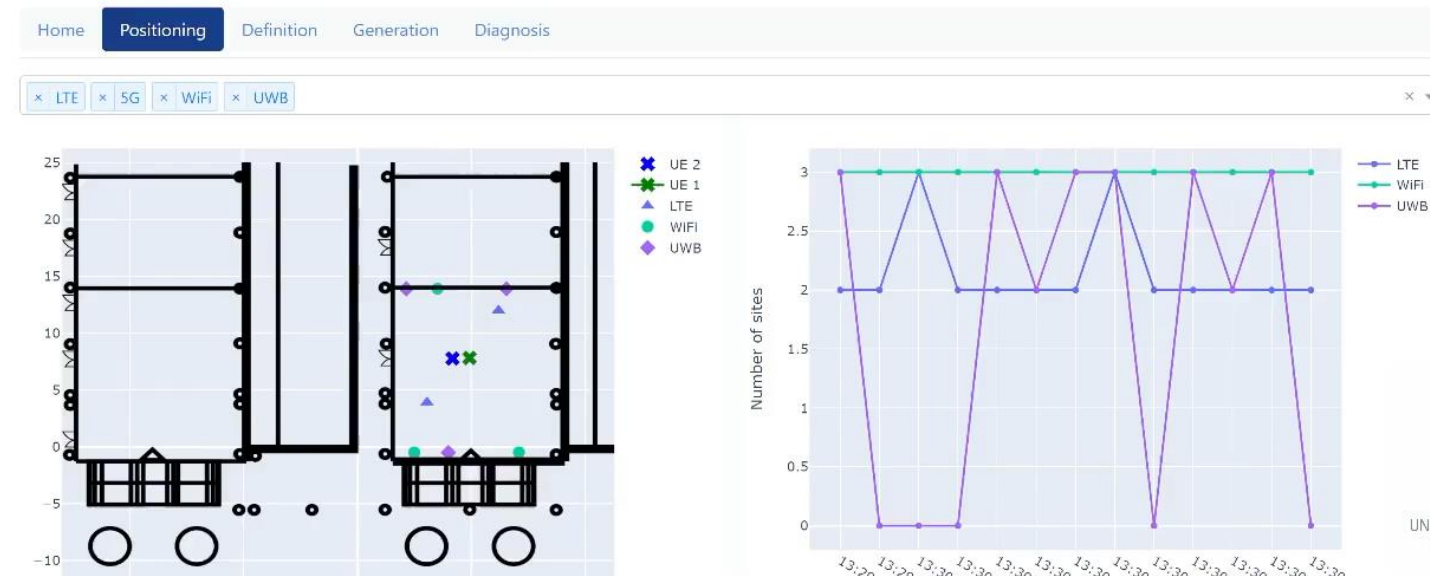
- Web interfaces, multisensory, rabbitMQ - LOCUS

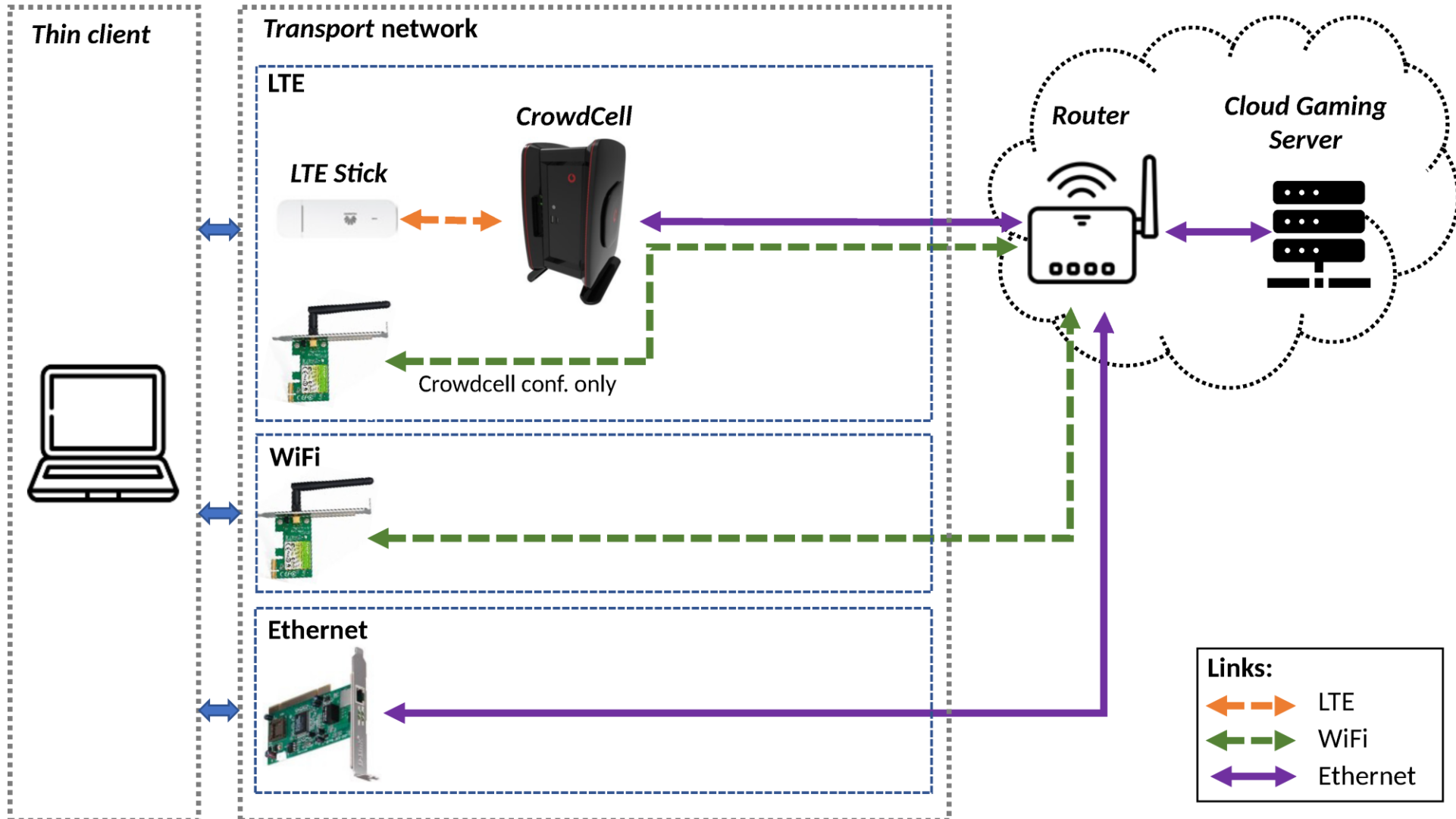


Name	Type	Features	Message rate in	Message rate out	+/-
(AMQP default)	direct	D			
Clear_Data	fanout		1.6/s	1.6/s	
ContextIndUpdate	fanout		0.20/s	0.40/s	
Diagnosis_topic	fanout		0.40/s		
PositionAndNetworkInfo	direct		1.6/s	4.8/s	
Raw_Data	fanout		1.6/s	1.8/s	
amq.direct	direct	D			
amq.fanout	fanout	D			

LOCUS: LOCalization and analytics on-demand embedded in the 5G ecosystem, for Ubiquitous vertical ApplicationS

PoC #1: Smart Network Management based on 5G equipment localization





The screenshot shows the PyCharm IDE interface. The top toolbar includes menus like File, Edit, View, Navigate, Code, Refactor, Run, Tools, VCS, Window, and Help. The project name is 'ClientDemo' and the current file is 'cloudGamingTestbed.py'. The left sidebar shows a file explorer with a tree view of the project structure, including folders like 'ClientDemo [Client]', '.vscode', 'cloudGaming', 'Moonlight', 'coordinates', 'iperf3-python', 'network', 'prueba', 'results', 'utils', and 'videoCapturing'. The main editor window displays the code for 'cloudGamingTestbed.py', which includes a try-except block for handling API requests and a loop for saving data. The terminal at the bottom shows the execution of the code, with output from the 'Macro.py' file.

```
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517

try:
    stats = crowd.stats()
except:
    stats = {}
# cellStats.append(stats)
ress = dict()
ress = configuration

ress.update(ue_stats)
ress.update(stats)
ress.update(kpi)
ress.update(kqi)
ress.update(conf2)
#ress['timestamp_received_client'] = confAPI['timestamp_received_client']
#ress['timestamp_sent_client'] = datetime.timestamp(datetime.now())
allM.append(ress)

r = requests.post(urlAPI + "data/service", json=ress)

saveData(ress_kqi)

if __name__ == '__main__': while (1)
```

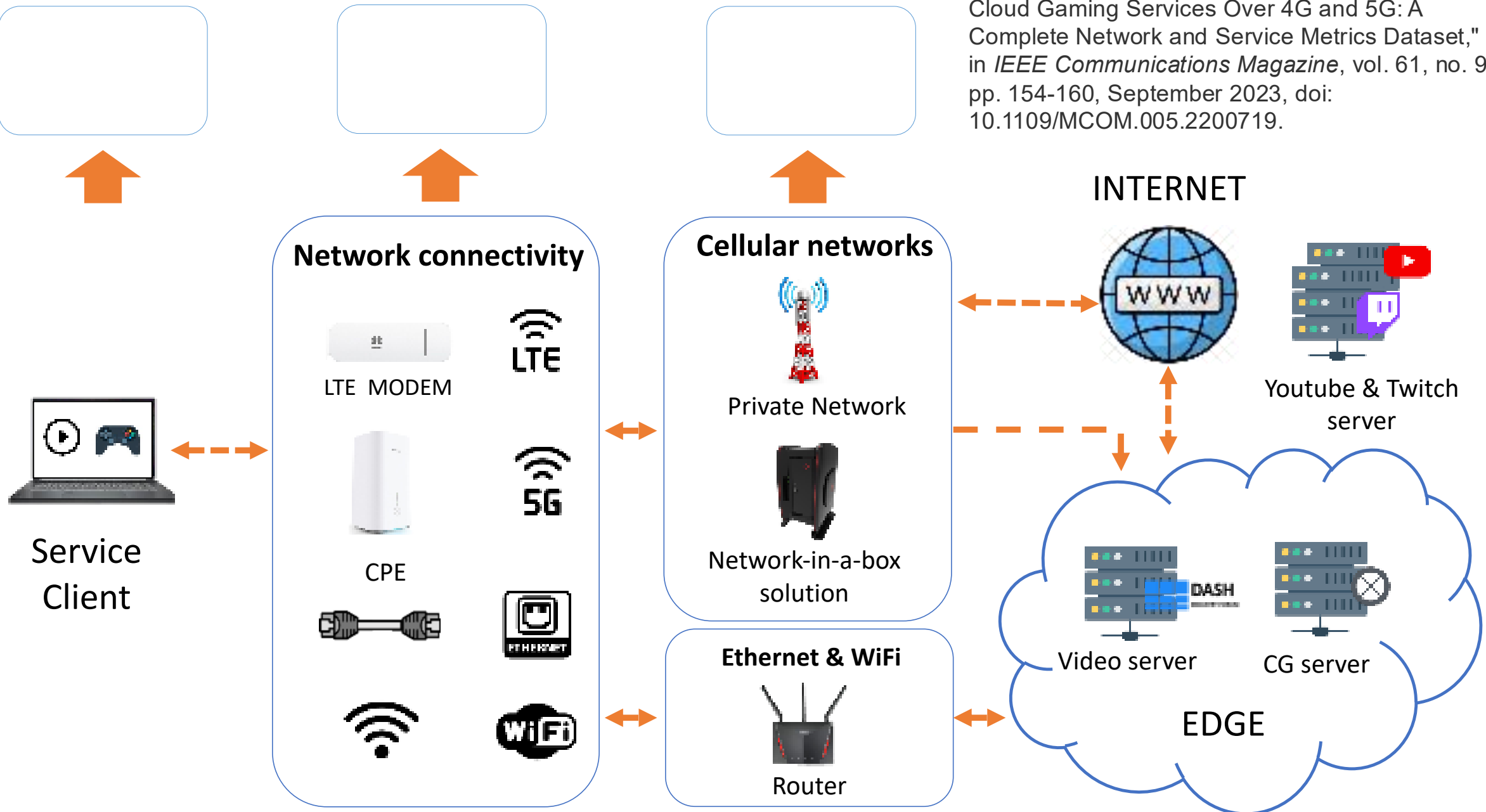
Terminal: Local (2) x Local x +

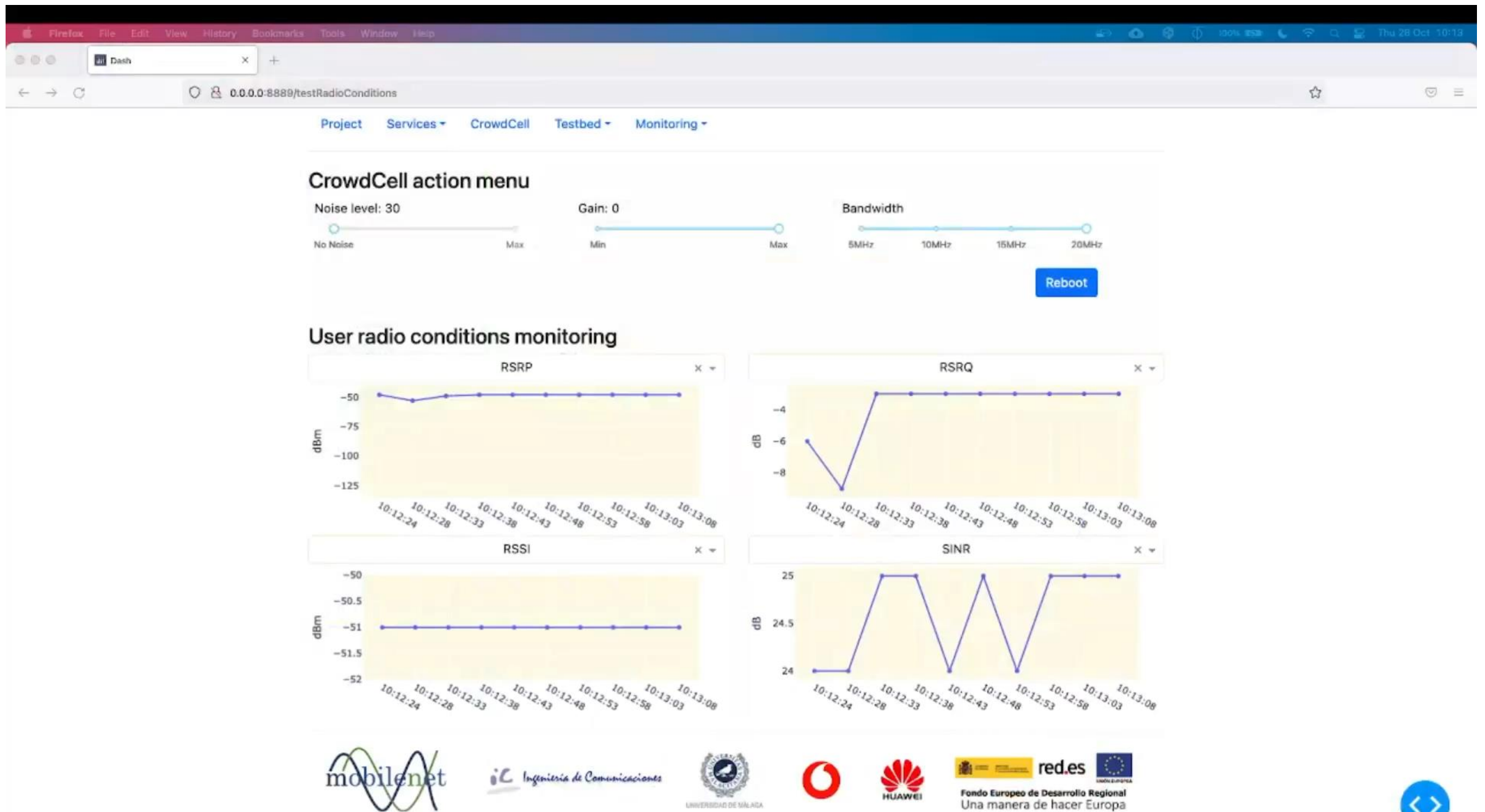
```
File "D:\CloudGaming\ClientDemo\cloudGaming\Moonlight\Macro.py", line 51, in conf_service
    config['audio'], config['decoder'], config['codec'])
File "D:\CloudGaming\ClientDemo\cloudGaming\Moonlight\Macro.py", line 82, in conf_Moonlight
    self.finish_configuration()
File "D:\CloudGaming\ClientDemo\cloudGaming\Moonlight\Macro.py", line 107, in finish_configuration
    time.sleep(1)
KeyboardInterrupt

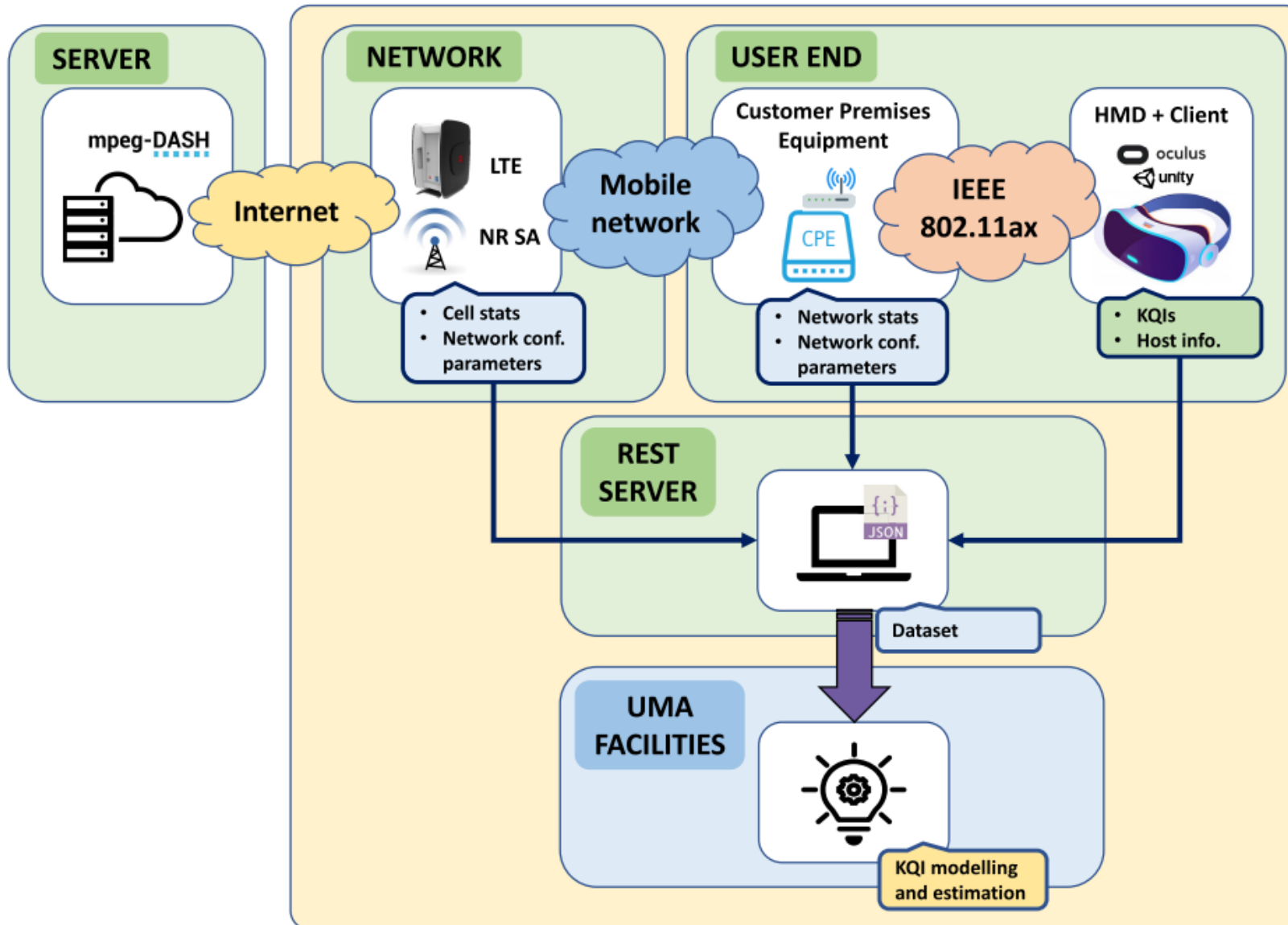
(Cloud Gaming) D:\CloudGaming\ClientDemo>
```

27 chars, 1 line break 516:1 CRLF UTF-8 4 spaces Git: master Python 3.7

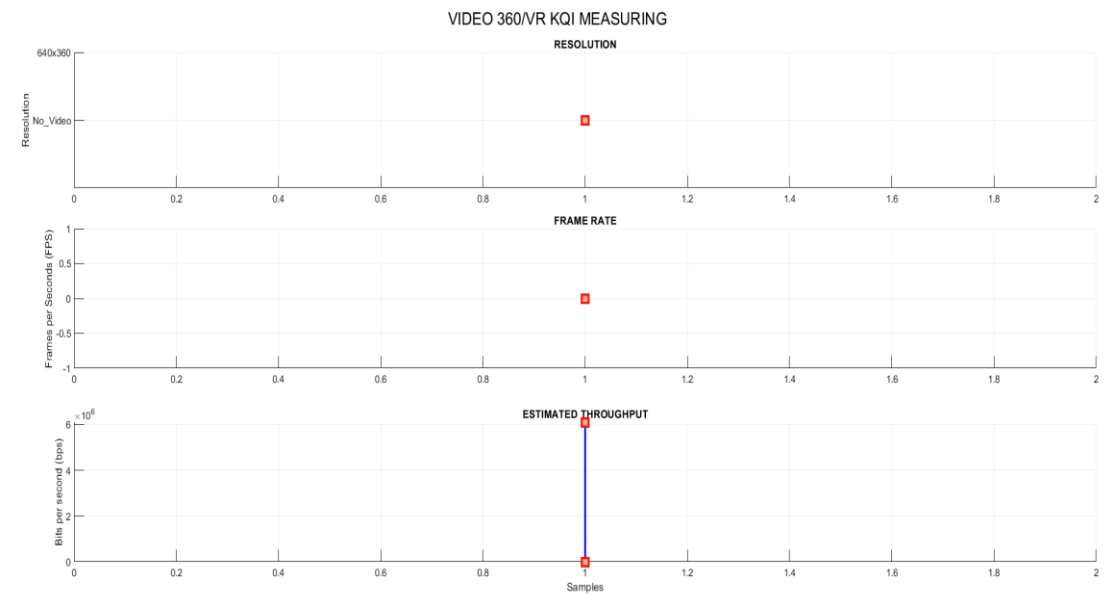
C. Baena, O. S. Peñaherrera-Pulla, L. Camacho, R. Barco and S. Fortes, "Video Streaming and Cloud Gaming Services Over 4G and 5G: A Complete Network and Service Metrics Dataset," in *IEEE Communications Magazine*, vol. 61, no. 9, pp. 154-160, September 2023, doi: 10.1109/MCOM.005.2200719.

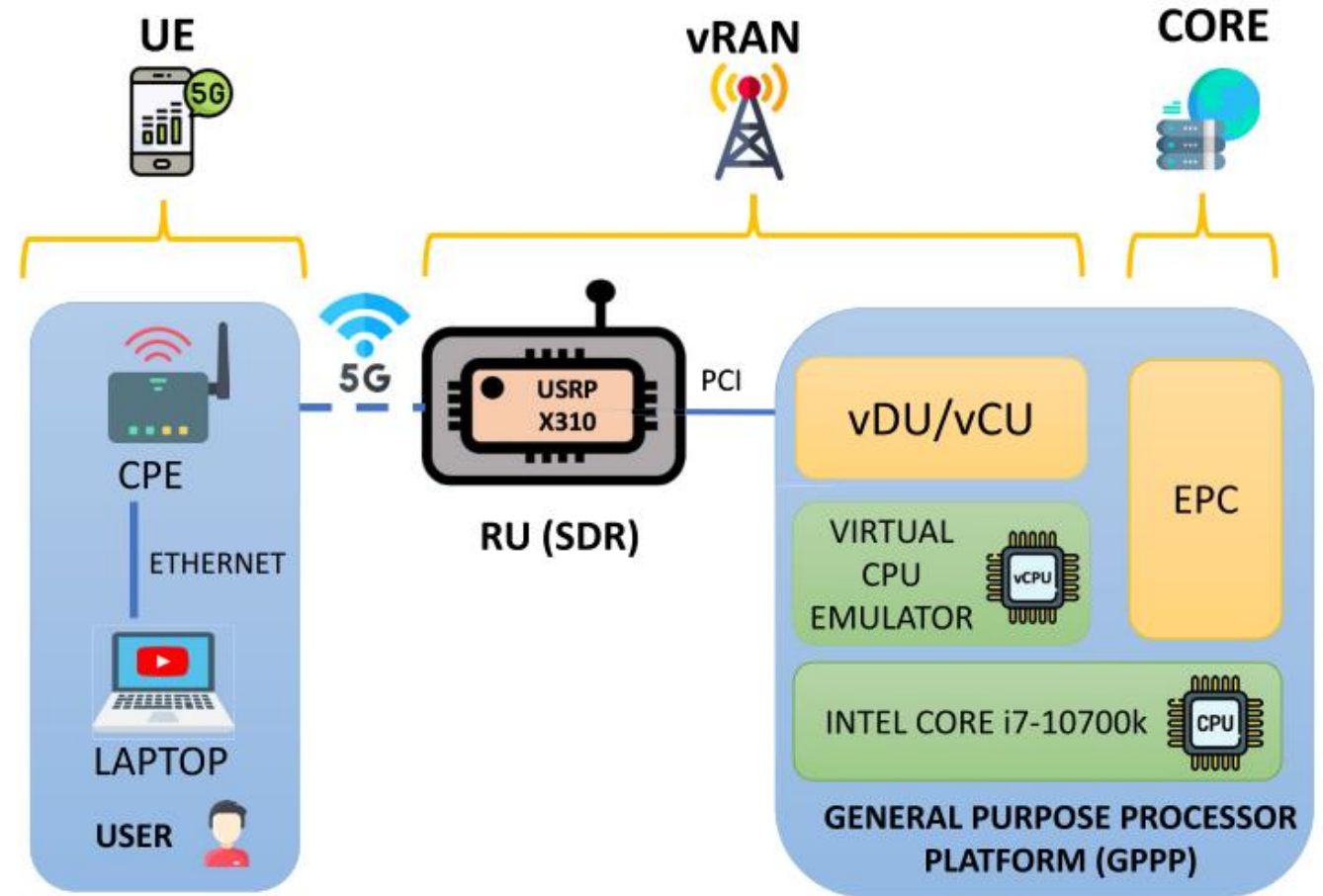
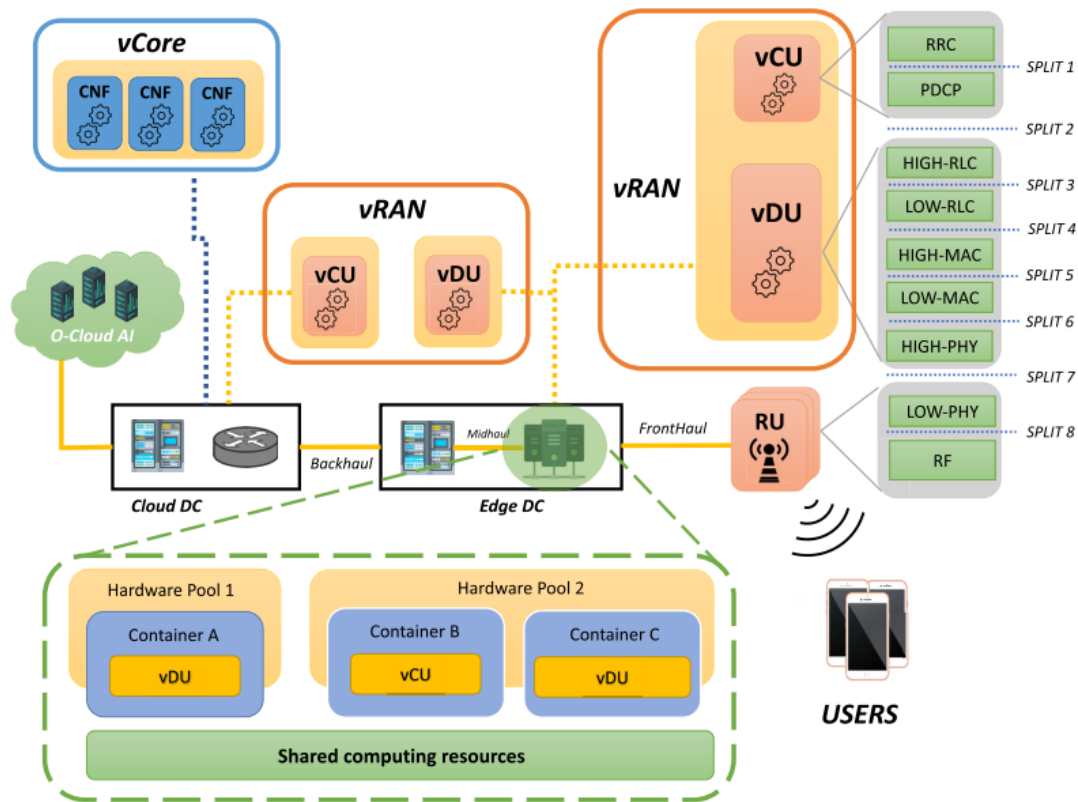






- VR





C. Baena, M. Hervás-Gutiérrez, E. Baena, J. Villegas, R. Barco and S. Fortes, "Assessing the Impact of Computational Resources to the Quality of Experience Provided by vRANs," in *IEEE Access*, vol. 11, pp. 102944-102948, 2023, doi: 10.1109/ACCESS.2023.3314853



UNIVERSIDAD
DE MÁLAGA



Computer-aware vRAN management for O-Cloud

María Hervás, Eduardo Baena, Carlos Baena, Javier Villegas, Sergio Fortes, Raquel Barco



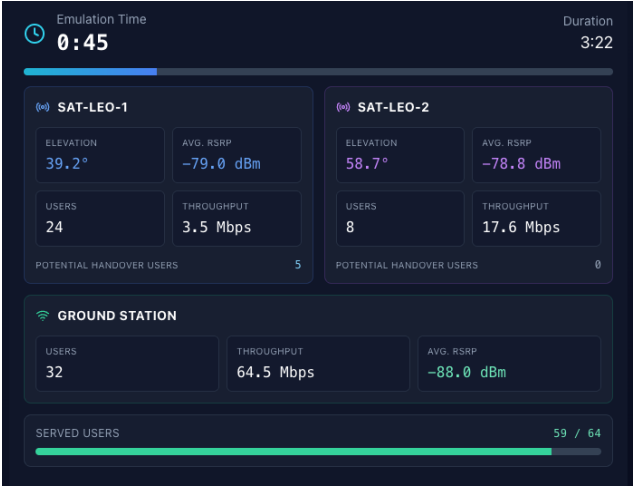
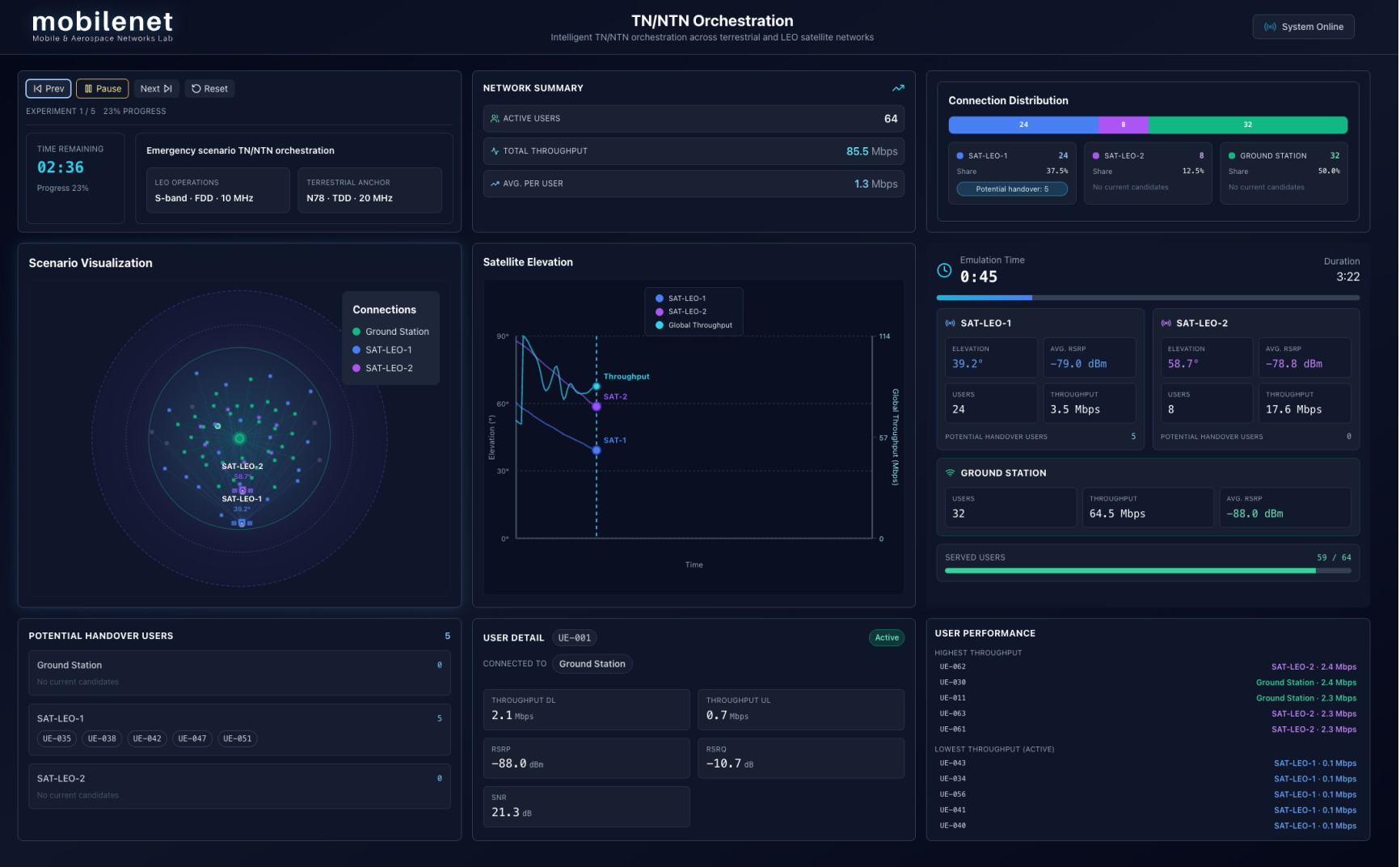
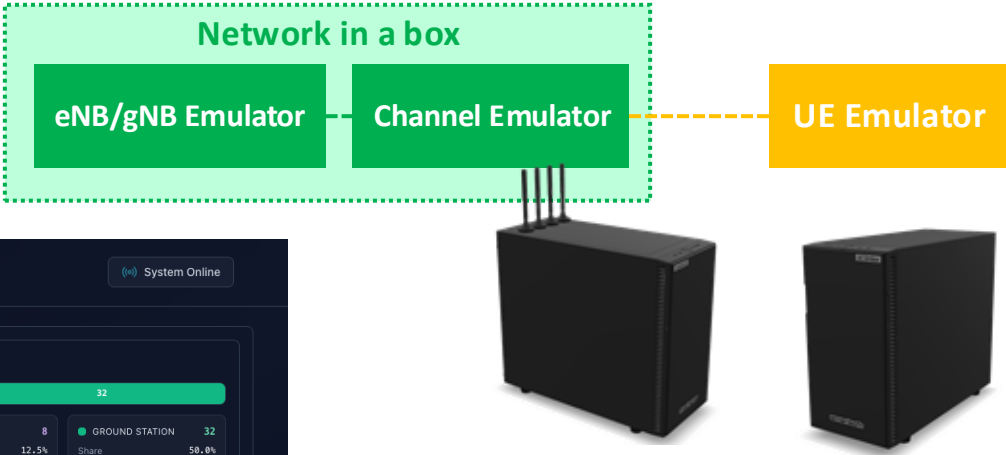
The undiscovered country...

the future

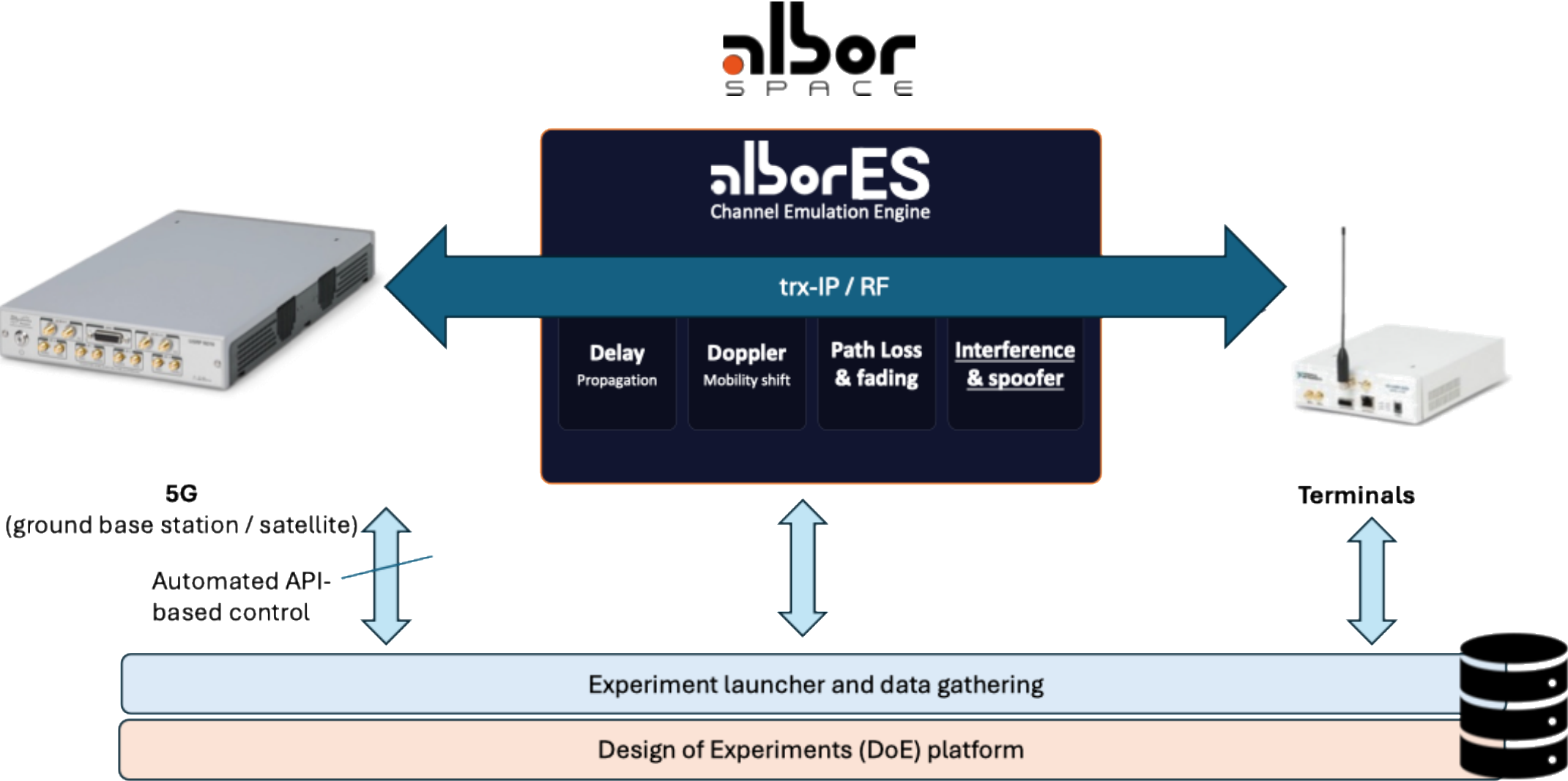
Challenges with NTN experimentation

- Complex scenario – mobility, pathloss, multiple BSs, multi orbit...
- Multiple architectures
- User and feeder links
- Various and high bands
- Special / incomplete SW stacks
- Limited experimentation time
- Expensive systems

Emulated NTN



Solutions

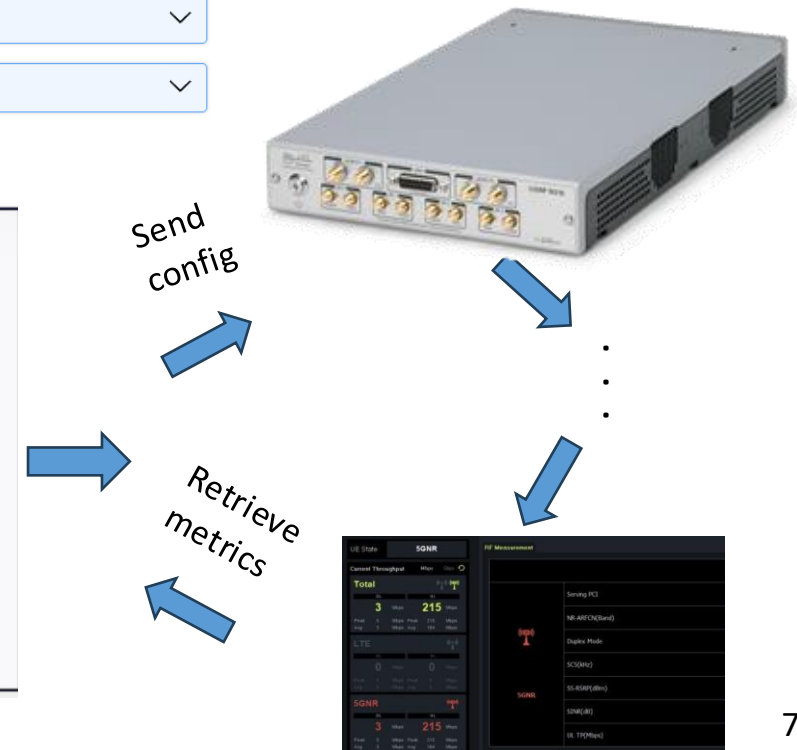
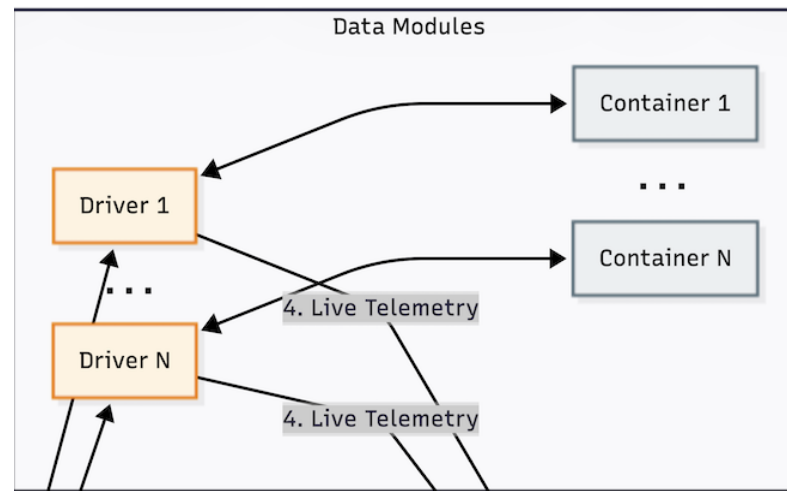
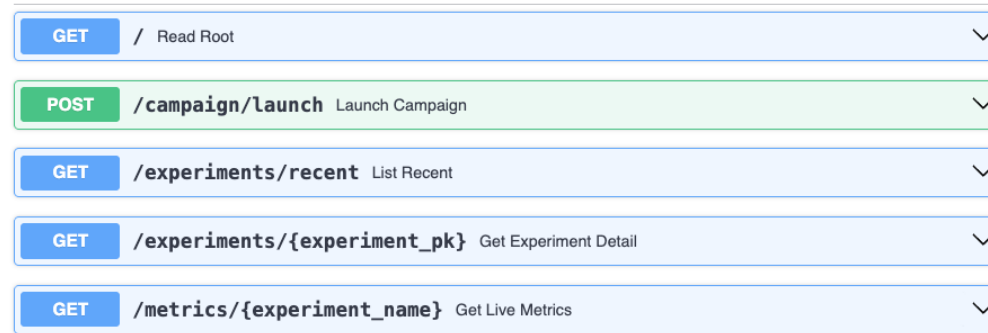


Framework for the Automation of Experimentation in Satellite Communications Testbeds

New framework

Experimentation Framework – Platform to deploy tests and retrieve results, connected to any desired equipment

- Modular and extensible
- Reproducibility
- Traceability
- Hardware-agnostic
- Canonic models
- Simulation, emulation
- Automated experimentation
- Complexity abstraction



Motivation & Objectives

Motivation:

- NTN as cutting edge technology
- Emerging heterogeneous equipment and tools
- Manual experimentation with concrete knowledge required
- Slowdown of manual experimentation

Objective: Design and implement an agnostic framework for the automation of experimentation oriented to NTN

Specific objectives:

- Define canonic configuration and telemetry models
- Design a modular and extensible architecture
- Implement the orchestration of the experiments
- Integrate persistence layer
- Validate the E2E

Requirements

Functional requirements:

- Define experiments in multiple nodes
- Execute experiments unattendedly
- Recollect and store telemetry in adequate storage systems
- Provide an operational interface

Non-functional requirements :

- Agnosticism
- Extensibility
- Reproducibility
- Traceability
- Robustness

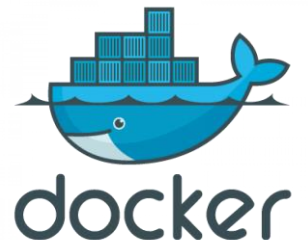
SoA

Standards:

- OpenConfig
- OpenTelemetry
- 3GPP

Technologies:

- gRPC
- PostgreSQL
- SQLite3
- InfluxDB
- MinIO
- Proxmox – LXC
- Docker



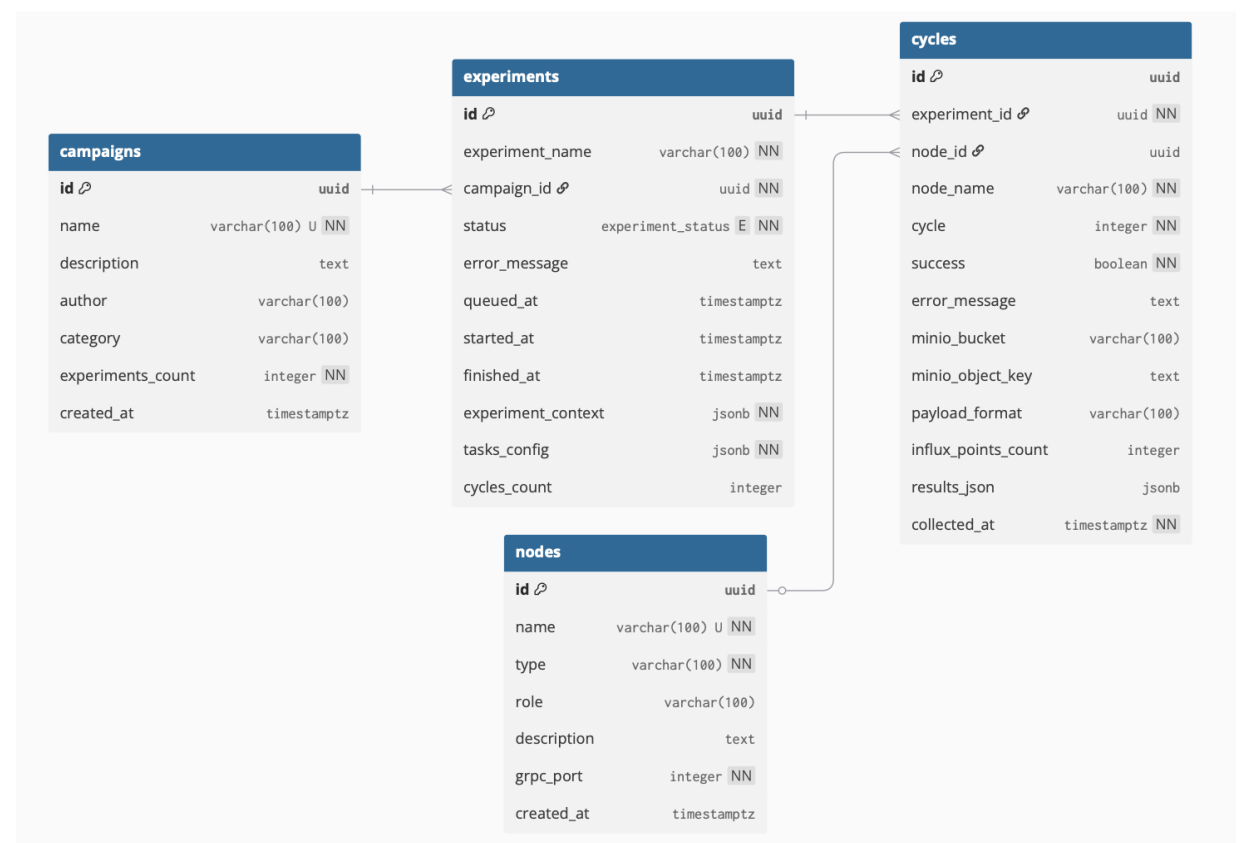
Approach

Modules:

- User Interface
- Core
- Drivers Layer
- Persistence Layer
- Analyzing model

Key factors:

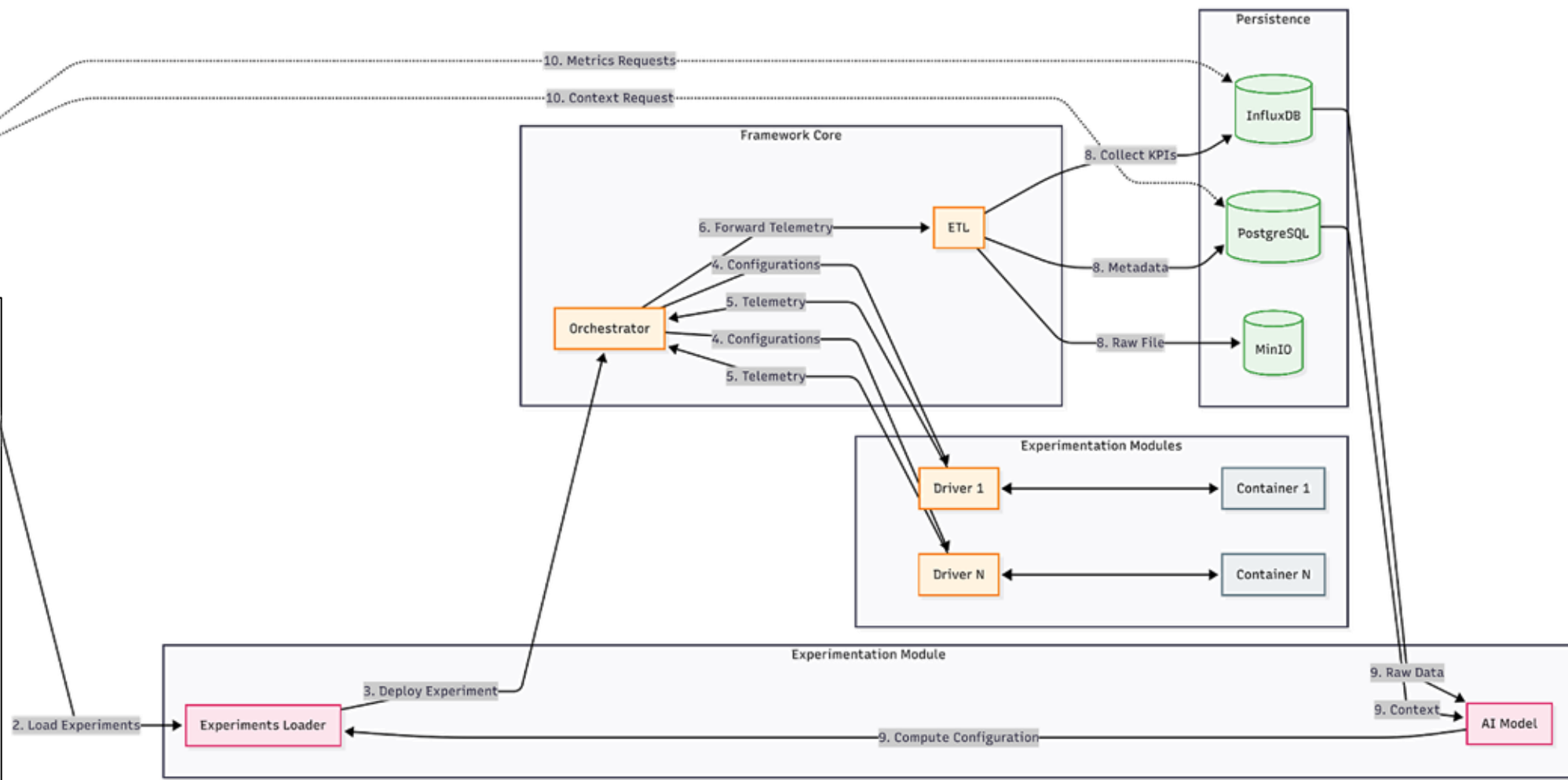
- Microservices + gRPC contracts or API requests
- Canonic models
- Strategy + Registry patterns
- Polyglot persistence



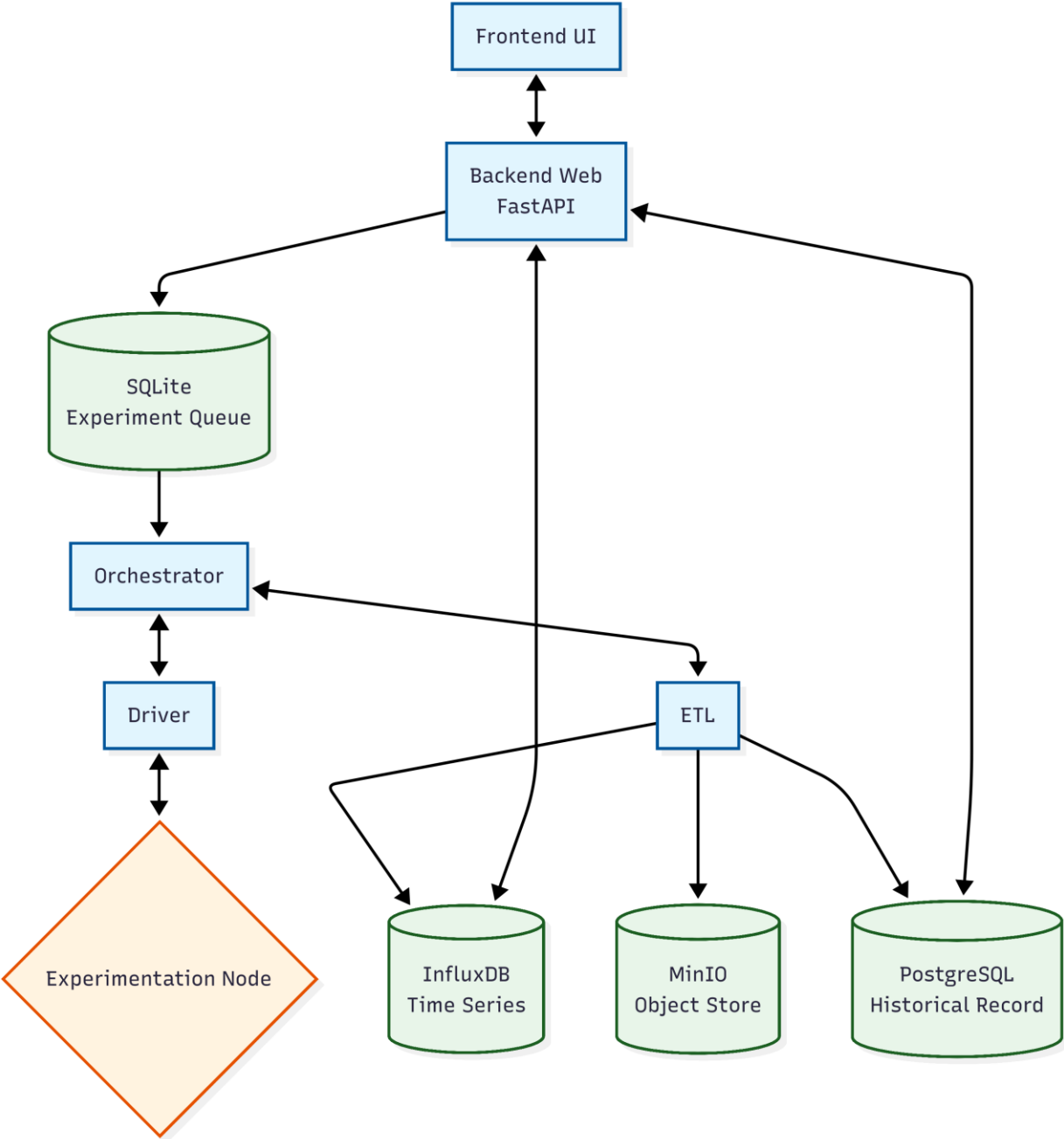
GET	/	Read Root	▼
POST	/campaign/launch	Launch Campaign	▼
GET	/experiments/recent	List Recent	▼
GET	/experiments/{experiment_pk}	Get Experiment Detail	▼
GET	/metrics/{experiment_name}	Get Live Metrics	▼

Workflow

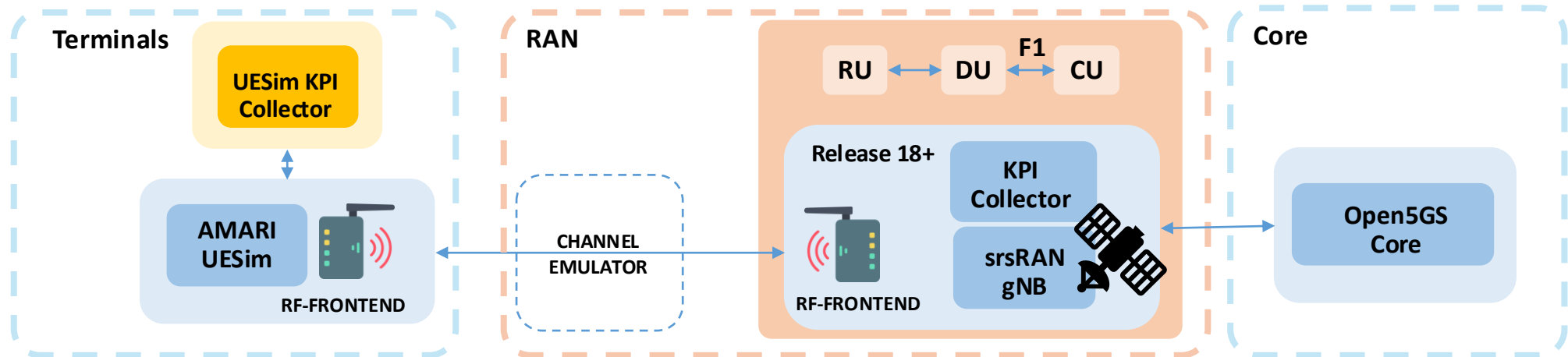
- Configuration storage
- Configuration dispatch to the nodes
- Experiments execution
- Results retrieval and transmission to the ETL
- Data extraction and dispatch to appropriate DBs
- Monitoring panels



Architecture



Validation & Use Case OCUDU gNB & UESimbox



Validation & Use Case

OCUDU gNB & UESimbox

Active UEs

12 ↗ up

Avg. E2E Throughput

750 Mbps

Avg. Latency

15 ms

Connected Devices

2/2

Experiment Configuration

Experiment Name

Experiment-886

BW (MHz)

20

DL ARFCN

368500

RU Slate

23,04

Duration (s)

30

Cycles

2

Granularity (s)

5

Node-specific gains

OCUDU gNB

TX Gain

75

RX Gain

75

UESIMBOX

TX Gain

20

RX Gain

20

Add to Queue

Experiment Queue

0 experiments

The queue is empty.

Live Performance Monitoring

Recent Experiments

Experiment-784 (COMPLETED) — Campaign-2026-05-19-669

Clear

Experiment-784 -- Campaign-2026-05-19-669

COMPLETED

Author

Researcher

Category

Performance

Cycles

3

Started at

19/05/2026, 12:30:02

Finished at

19/05/2026, 12:32:44

Cycles (6)

gnb-001 (0df7f3e7-dcf8-492a-86b3-373cf1902909, cycle 1)

ue-001 (f00618dd-0139-4429-9f5d-950dc36cd24d, cycle 1)

gnb-001 (0df7f3e7-dcf8-492a-86b3-373cf1902909, cycle 2)

ue-001 (f00618dd-0139-4429-9f5d-950dc36cd24d, cycle 2)

gnb-001 (0df7f3e7-dcf8-492a-86b3-373cf1902909, cycle 3)

ue-001 (f00618dd-0139-4429-9f5d-950dc36cd24d, cycle 3)

Downlink Bitrate (kb/s) desde InfluxDB

28000

19500

13000

6500

0

12:30:10

12:30:20

12:30:30

12:31:00

12:31:20

12:31:55

12:32:05

12:32:15

DL_BRATE

Connected Devices & Agents (Abstraction Layer)

Tool

gRPC agent

OCUDU gNB

Connected

UESimbox

Connected

2026-05-19 10:48:03 | INFO | orchestrator.dispatcher | → driver 0

ESimbox (ue-001) cycle 1

2026-05-19 10:48:37 | INFO | orchestrator.dispatcher | Cycle 1 /

ue-001: no telemetry, skipping ETL

2026-05-19 10:48:37 | INFO | orchestrator.dispatcher | Experiment

Experiment-496: cycle 1 completed

2026-05-19 10:48:37 | INFO | orchestrator.dispatcher | Experiment

Experiment-496: cycle 2/2 starting

2026-05-19 10:48:37 | INFO | orchestrator.dispatcher | Phase 1: l

aunching 1 task(s) in parallel

2026-05-19 10:48:37 | INFO | orchestrator.dispatcher | → driver 0

CUDU_gNB (gnb-001) cycle 2

2026-05-19 10:48:37 | INFO | orchestrator.dispatcher | Waiting 5s

before phase 2

2026-05-19 10:48:42 | INFO | orchestrator.dispatcher | Phase 2: l

aunching 1 task(s) in parallel

2026-05-19 10:48:42 | INFO | orchestrator.dispatcher | → driver 0

ESimbox (ue-001) cycle 2

2026-05-19 10:49:16 | INFO | orchestrator.dispatcher | Cycle 2 /

ue-001: no telemetry, skipping ETL

2026-05-19 10:49:16 | INFO | orchestrator.dispatcher | Experiment

Experiment-496: cycle 2 completed

2026-05-19 10:49:16 | INFO | orchestrator.dispatcher | Experiment

Experiment-496: starting cleanup phase

2026-05-19 10:49:16 | INFO | orchestrator.dispatcher | Cleanup OK

: gnb-001 (OCUDU_gNB)

2026-05-19 10:49:16 | INFO | orchestrator.dispatcher | Cleanup OK

: ue-001 (UESimbox)

2026-05-19 10:49:16 | INFO | orchestrator.dispatcher | Experiment

Experiment-496 → FAILED

File "/root/framework/.venv/lib/python3.12/site-packages/grpc/_common.py", line 154, in wait

_wait_once(wait_fn, MAXIMUM_WAIT_TIMEOUT, spin_cb)

File "/root/framework/.venv/lib/python3.12/site-packages/grpc/_common.py", line 114, in _wait_once

wait_fn(timeout=timeout)

File "/usr/lib/python3.12/threading.py", line 655, in wait

signaled = self._cond.wait(timeout)

File "/usr/lib/python3.12/threading.py", line 359, in wait

gotit = waiter.acquire(True, timeout)

KeyboardInterrupt

(.venv) root@framework-msi:~/framework/backend# python3 -m etl.main

2026-05-19 10:08:44 | INFO | etl | ETL service lis

tening on :50052

2026-05-19 10:08:44 | INFO | etl |

Parsers loaded: ['xml3gpp_28550']

[ETL] Received Experiment-541 / gnb-001 / cycle 1 / format xml3gpp_28550

[ETL] Received Experiment-541 / gnb-001 / cycle 2 / format xml3gpp_28550

[ETL] Received Experiment-389 / gnb-001 / cycle 1 / format xml3gpp_28550

[ETL] Received Experiment-389 / gnb-001 / cycle 2 / format xml3gpp_28550

[ETL] Received Experiment-495 / gnb-001 / cycle 1 / format xml3gpp_28550

[ETL] Received Experiment-495 / gnb-001 / cycle 2 / format xml3gpp_28550

[ETL] Received Experiment-495 / gnb-001 / cycle 3 / format xml3gpp_28550

[ETL] Received Experiment-784 / gnb-001 / cycle 1 / format xml3gpp_28550

[ETL] Received Experiment-784 / gnb-001 / cycle 2 / format xml3gpp_28550

[ETL] Received Experiment-784 / gnb-001 / cycle 3 / format xml3gpp_28550

File "/root/framework/backend/drivers/ocudu_gnb/service.py", line 57, in SendConfig

xml_payload = self._executor.run_experiment(

xml_payload = self._executor.run_experiment(

File "/root/framework/backend/drivers/ocudu_gnb/ssh_executor.py", line 67, in run_experiment

return self._fetch_xml_to_memory(sftp, xml_remote_path)

File "/root/framework/backend/drivers/ocudu_gnb/ssh_executor.py", line 157, in _fetch_xml_to_memory

sftp.getfo(remote_path, buffer)

File "/root/framework/.venv/lib/python3.12/site-packages/paramiko/sftp_p_client.py", line 795, in getfo

file_size = self.stat(remotepath).st_size

File "/root/framework/.venv/lib/python3.12/site-packages/paramiko/sftp_p_client.py", line 493, in stat

t, msg = self._request(CMD_STAT, path)

File "/root/framework/.venv/lib/python3.12/site-packages/paramiko/sftp_p_client.py", line 857, in _request

return self._read_response(num)

File "/root/framework/.venv/lib/python3.12/site-packages/paramiko/sftp_p_client.py", line 909, in _read_response

self._convert_status(msg)

File "/root/framework/.venv/lib/python3.12/site-packages/paramiko/sftp_p_client.py", line 938, in _convert_status

raise IOError(errno, text)

FileNotFoundError: [Errno 2] No such file

2026-05-19 10:49:16 | INFO | driver.ocudu_gnb.service | Cleanup called for gnb-001 — nothing to do (gNB stops per cycle)

[UE] /root

[UE] stop lte service: service lte stop

[UE] link config: ln -sf /tmp/ue_config_Experiment-496_cycle1.cfg /root/ue/config/ue.cfg

[UE] check config: ls -l /root/ue/config/ue.cfg

[UE] lrwxrwxrwx 1 root root 40 May 19 10:48 /root/ue/config/ue.cfg → /tmp/ue_config_Experiment-496_cycle1.cfg

[UE] start lte service: service lte start

[UE] Cycle running (30s)...

[UE] Cycle 1 duration elapsed

[UE] Stopping LTE service to close cycle 1

[UE] stop lte service: service lte stop

2026-05-19 10:48:42 | INFO | driver.uesimbox.service | Cycle 2 for experiment-Experiment-496 node-ue-001

[UE] DEBUG: uploaded /tmp/ue_config_Experiment-496_cycle2.cfg → 2551 bytes

[UE] user check: whoami && pwd

[UE] root

[UE] /root

[UE] stop lte service: service lte stop

[UE] link config: ln -sf /tmp/ue_config_Experiment-496_cycle2.cfg /root/ue/config/ue.cfg

[UE] check config: ls -l /root/ue/config/ue.cfg

[UE] lrwxrwxrwx 1 root root 40 May 19 10:48 /root/ue/config/ue.cfg → /tmp/ue_config_Experiment-496_cycle2.cfg

[UE] start lte service: service lte start

[UE] Cycle running (30s)...

[UE] Cycle 2 duration elapsed

[UE] Stopping LTE service to close cycle 2

[UE] stop lte service: service lte stop

2026-05-19 10:49:16 | INFO | driver.uesimbox.service | Cleanup called for ue-001 — stopping LTE service

[UE] stop lte service: service lte stop

New Node Integration

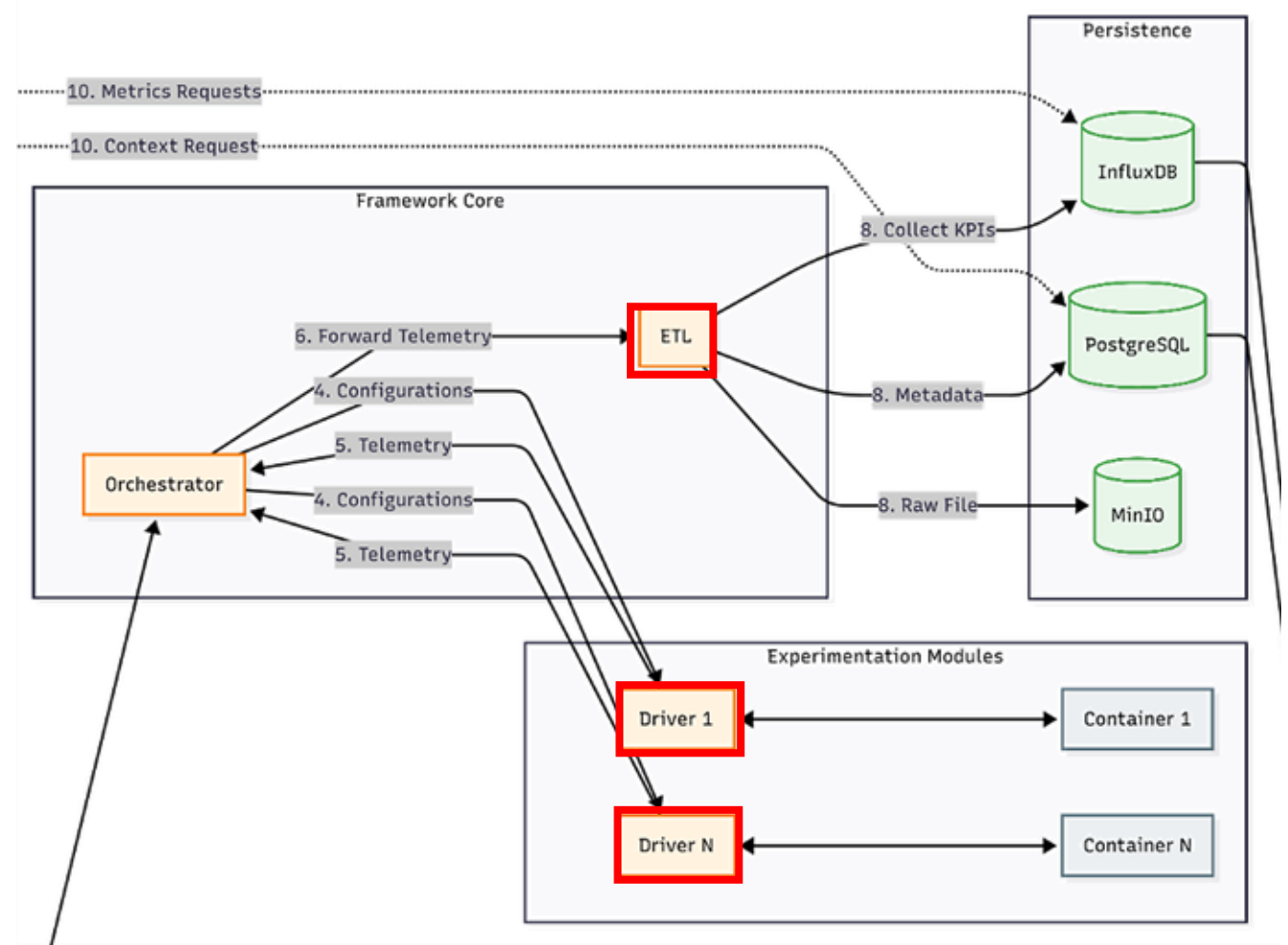
Required implementations:

- Driver
- Parser (ETL)

Required actions:

- Driver registry
- Parser registry

The framework core logic is not modified, neither the orchestrator, the ETL nor the backend web modules.



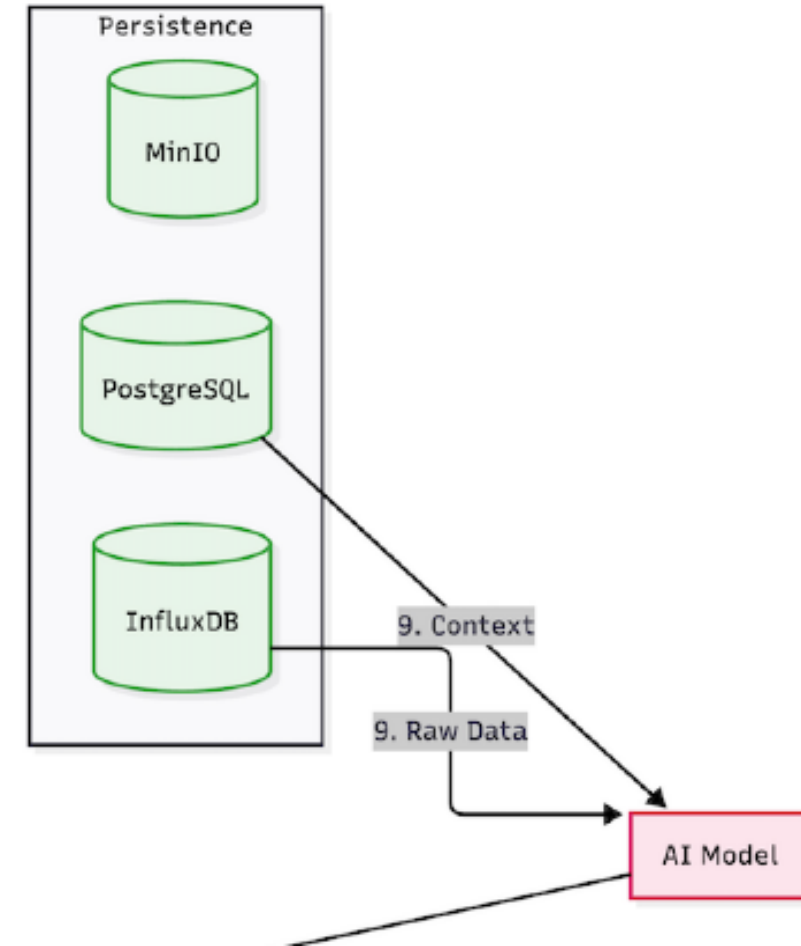
Conclusions & Future Lines

- Functional agnostic framework, validated with two equipment from the testbed
- Canonic models
- Modular architecture
- Complete E2E

Reduction of the integration cost of new equipment, optimize experimentation required time and avoid technical knowledge of the equipment.

Future Lines:

- AI model
- Standards integration
- Extend the integrated testbed





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SLICES Integration

Planning:

- Start with one experiment
- Grow from there

Paths:

- Integration of basic infrastructure, such as SDRs and servers
- NTN blueprint containing the complete scenario to deploy
- Adapt the API the endpoints of other tools to make it compatible with the platform API

Status:

- Currently in the process to update our experimentations setup -> “SLICES– native”

Wrap-up

Conclusions & Future Lines

- The Mobilenet team has a key role in multiple projects related with Self-Organizing Networks, 5G/6G, localization and the application of AI/machine learning techniques for cellular and IoT networks as well as smart city applications, avionics, security and satcom.
- Infrastructure as a service as a key pillar of research.
- Need for automated experiment execution and data gathering.
- New platforms and systems are needed.
- Convergence to SLICES.

An industry in Málaga!



...

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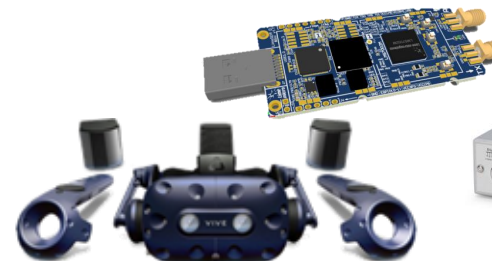
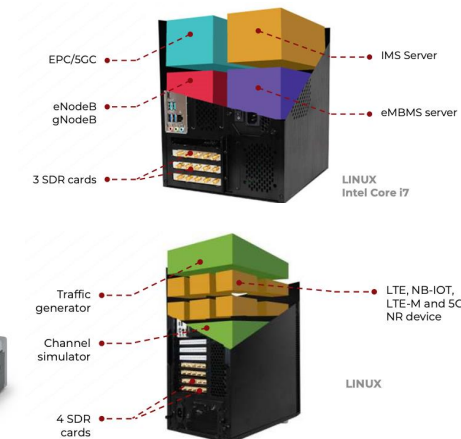
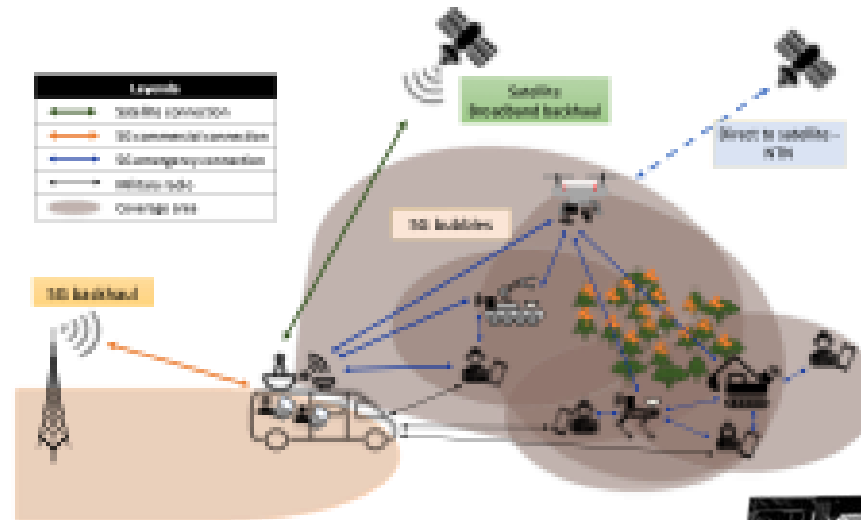


linkedin.com/in/sergiofortes

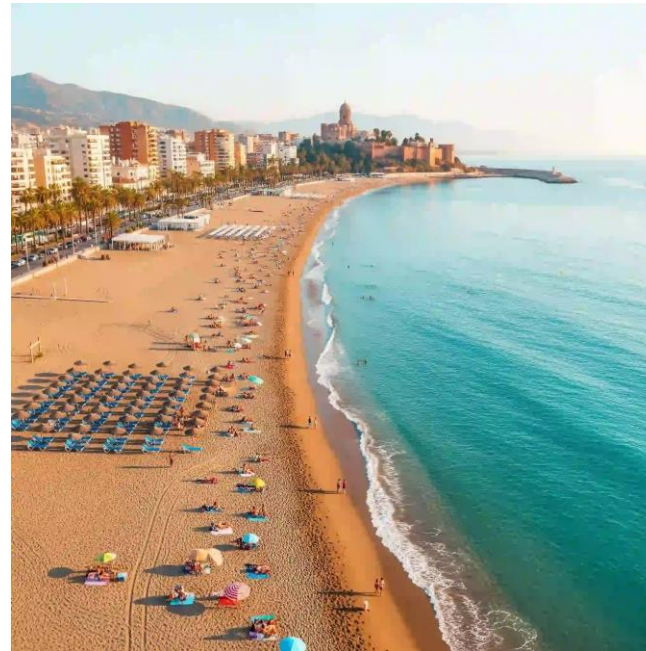


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Thanks!!



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