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Industrial O-RAN Deployment

Insights from Single-Cell Co-Channel gNB Analysis

Hubert Djuitcheu, Andrew Sergeev, Achim Autenrieth, Jörg-Peter Elbers, Jochen Seitz, May 2025

Outline

- Introduction to 6G-Terafactory
- Motivation
- Concept and Setup
- Experimental results
- Conclusion & Outlook

6G-TeraFactory

6G-Terafactory

6G TERAFACTORY

Federal Ministry of Research, Technology and Space

Open RAN based campus network for industrial real-time applications

- Duration: 01.01.2023 – 31.12.2025
- Budget: 4,34 M€

Adtran

dfki Deutsches Forschungszentrum für Künstliche Intelligenz German Research Center for Artificial Intelligence

HOCHSCHULE SCHMALKALDEN UNIVERSITY OF APPLIED SCIENCES

MetraLabs mobile robots

GESTALT ROBOTICS

What is 6G-Terafactory?

Goals

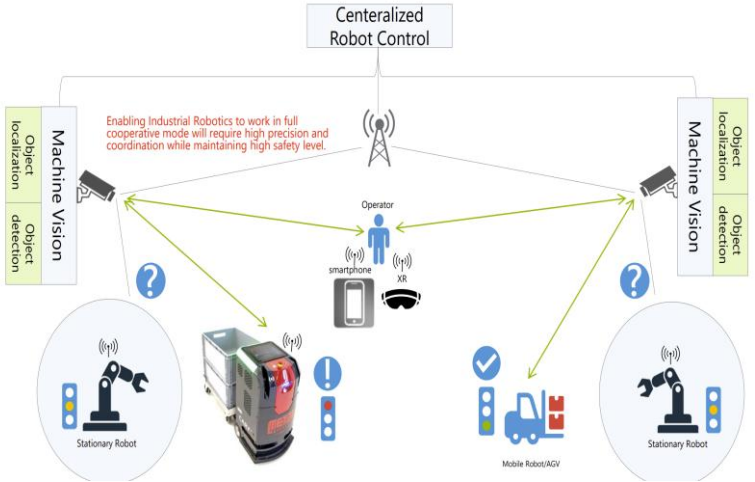
- Designing campus networks for industrial real-time applications
- Optimizing network operations through functional simplification
- Assist the production and reduce the work processes

Use cases

- Real-time goods tracking & autonomous driving
- Fully automated product provisioning
- Extended Reality (XR) as support for employees

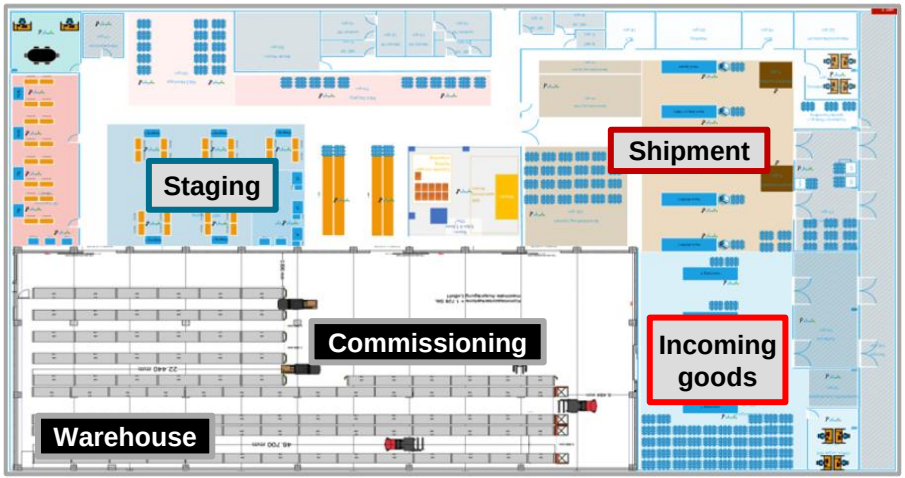
Research focuses

- O-RAN resilience and security analysis
- Indoor positioning, Time Sensitive Network (TSN)
- Automated radio resource management and optimization



O-RAN meets industry

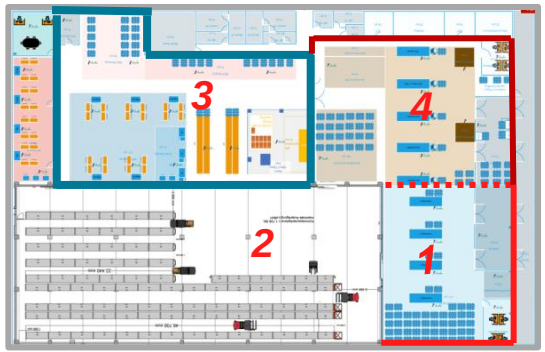
- Enable industrial innovation and experimentation
  - Adtran private 5G/6G network
  - Deploy advanced wireless infrastructure to support existing technology
- Achieve cost efficiency
  - Leverage open-source solutions to reduce CAPEX & OPEX
- Enhance Adtran product functionality
  - Integrate some O-RAN benefits to improve the features and performance of some products
- Ensure low-latency, reliable, secure, and robust communication across the factory



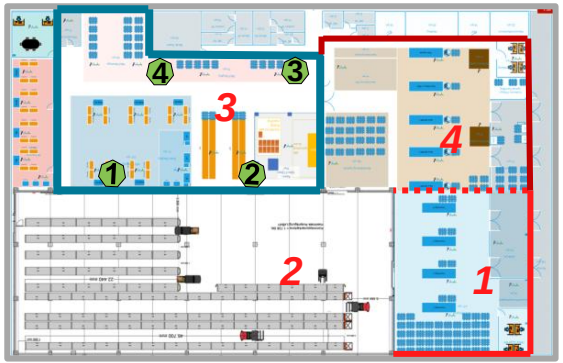
Deployment plan

- Procurement of appropriate hardware/software
- Division of the factory into 4 distinct coverage zones
- Network dimensioning and simulation for initial validation
- Pilot deployment and testing in room 3
  - Coexistence test with the existing industrial system
  - followed by full-scale deployment in the remaining rooms

Final stage



Stage 0



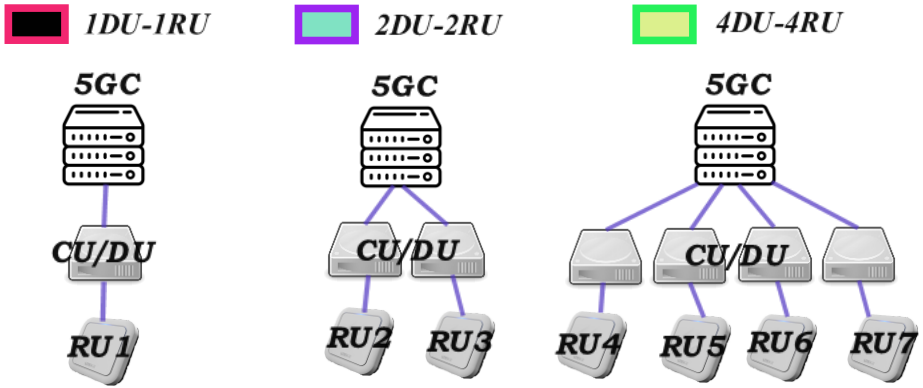
Stage 1&2

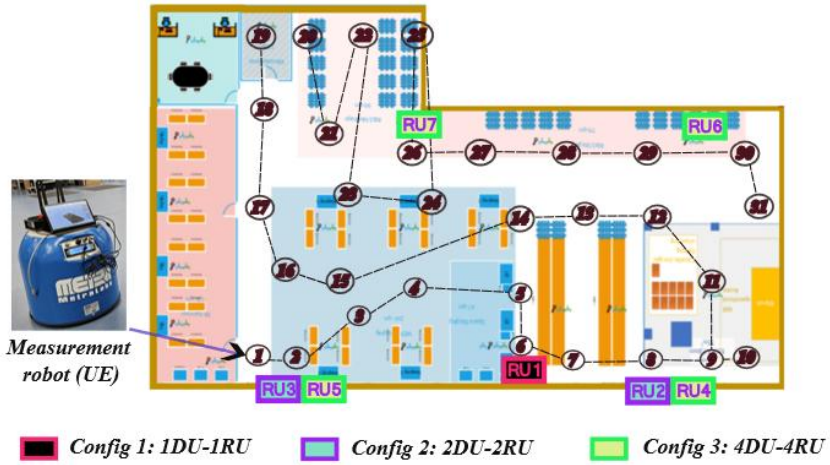
Multivendor RU support

- *Benetel*
- *WNC*
- *Liteon*

Setup

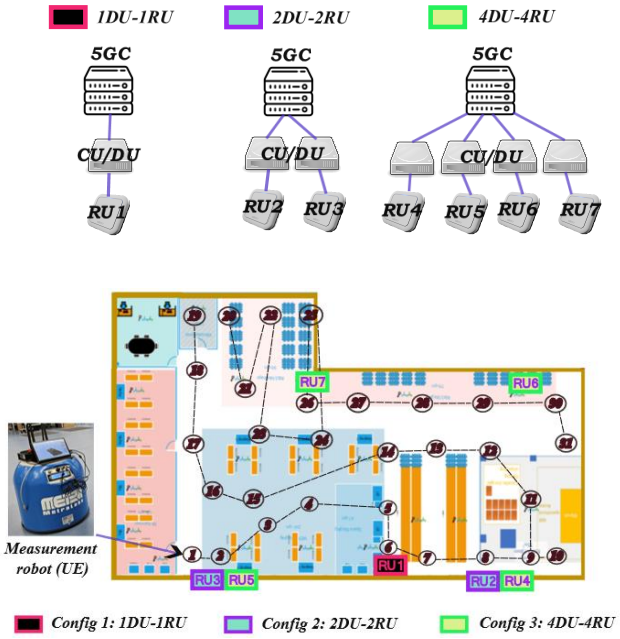
- 3 Network configurations:
  - **Configuration 1**(1CU/DU-1RU); **configuration 2**: 2CU/DU-2RU; **configuration 3**: 4CU/DU-4RU
  - RU mounted at 6m (ceiling) and UE positioned at 0.6m (ground)
- gNB+RU: TDD, 100MHz, TX=18dBm, 4X4 MIMO, 7.2x
- 5GC & gNB configuration from OpenAirInterface (OAI)





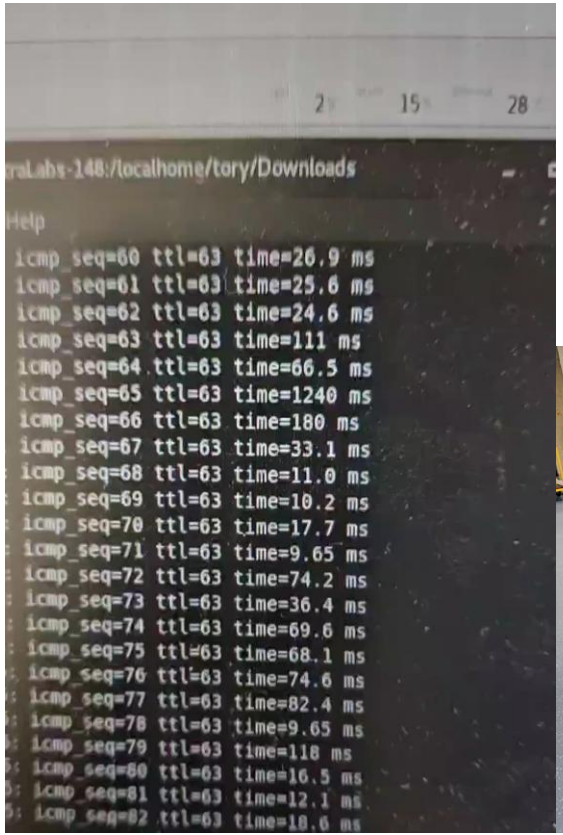
Setup

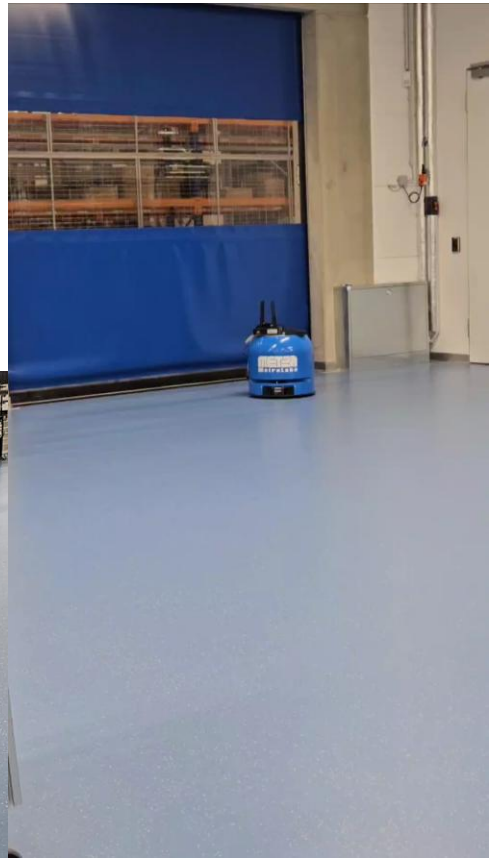
- Selected KPIs for evaluation
  - Latency, Jitter, SINR, RSRP, and Throughput
  - Tools: Ping, Iperf, AT Commands
- Measurement point selection and Room constraints
  - 31 strategically selected points in the 650 m*2
  - Several large industrial machines and obstacles in the room
- Automated KPI measurement setup
  - Tory device + Modem + SIM-Card + Custom measurement script
  - Collecting KPIs at one point, then driving to the next point



Experimental results

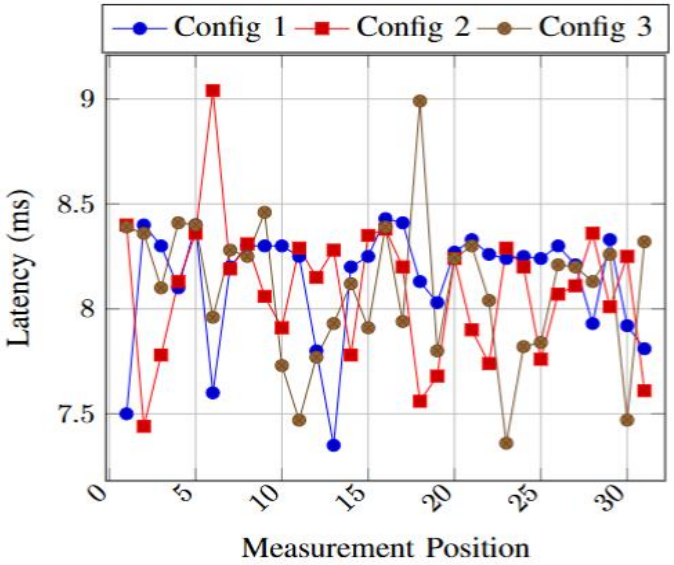
Automated KPI measurement Demo

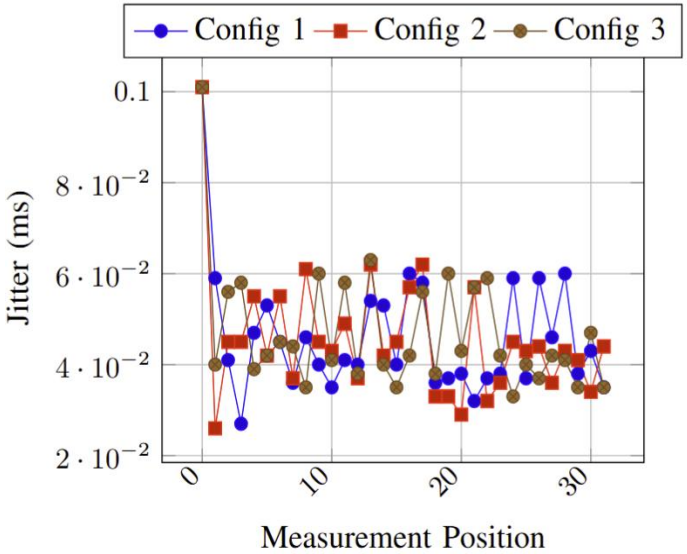




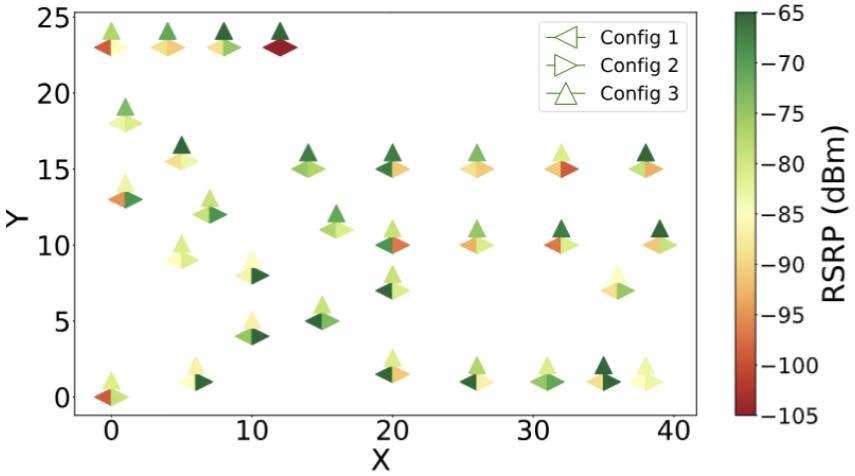
Latency, Jitter & Throughput

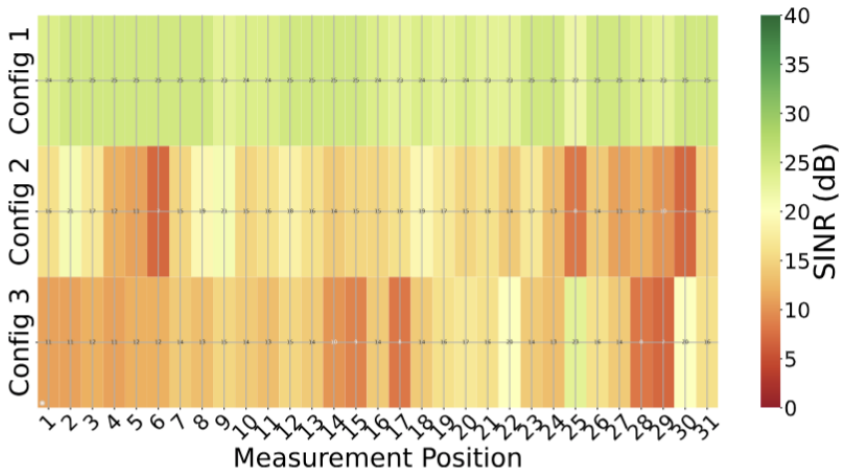
- DL-Throughput limited to 240 Mbps due to Raspberry Pi constraints
- Consistently low average latency across all configurations, staying under 8.5 ms.
- All configurations exhibit consistently stable jitter across all measurements, with occasional spikes.





Signal quality



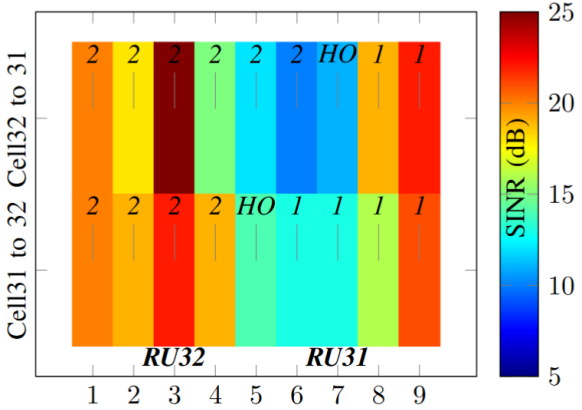


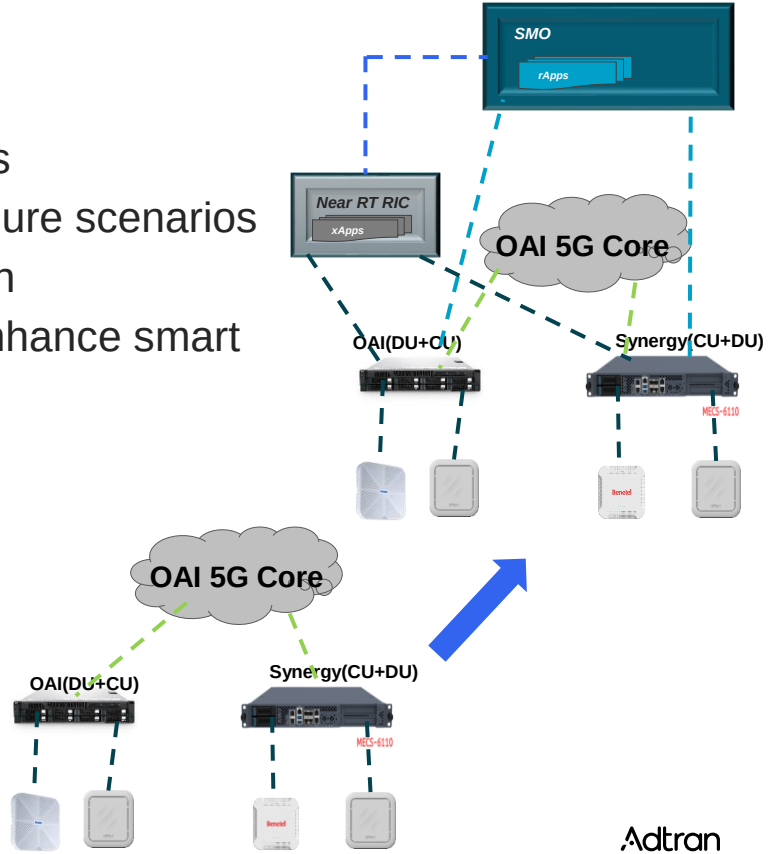
- 3 network configuration results
  - Config1: shows high SINR, but poor RSRP performance
  - Config2: shows balanced performance
  - Config3: shows strong RSRP, but degraded SINR
- Co-channel single-cell setups improve coverage but increase in-room
- Poor SINR may result from late HO decision?

Conclusion & Outlook

How to secure and build a resilient O-RAN network?

- Interoperability testing
  - O-RAN component from different Vendors
- Handover mechanism (Hard & F1-Handover) analysis
- System resilience assessment under various gNB failure scenarios
- MAC scheduler security and vulnerability investigation
- Integrate more O-RAN elements (RIC, SMO,…) to enhance smart Handover, security, and resilience management





Thank you

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Backup Slides

Research opportunities

Security and security resilience

- Security analysis of new interfaces and components
- Develop some ML algorithms for anomaly detection and prevention
- How to manage untrusted gNB, and DoS attacks from malicious UE?
- How to secure the communication protocols?

Network resilience

- How to maintain the O-RAN system secure and recover after a failure?
- How to ensure coexistence with industrial WiFi?
- Develop some techniques to detect and adjust automatically to changing network conditions.

Availability and Stability

- How to ensure minimal downtime?
- How to smartly implement load balancing?
- Use of ML/AI to predict and prevent potential failures

Interoperability

- How to test and validate the interoperability of Hardware and software from different Providers?

Energy Consumption

- Develop techniques and algorithms to optimize and adjust power usage

CI/CD

- Deploy a MANO into the network to automate some tasks
- How to integrate DevOps to the testing, and deployment processes?

5G/6G localization service

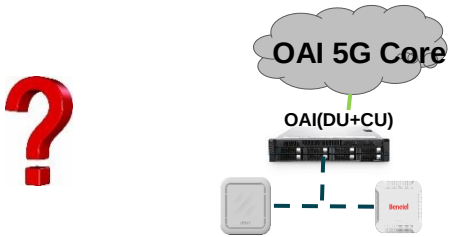
- Implementation of real-time indoor positioning system

Management and monitoring

- Develop an extension to MeshView application for private 5G network
- Develop a minimalistic Dashboard for the RAN monitoring

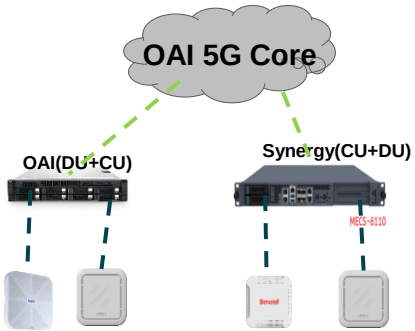
Deployment plan

Stage 0-1



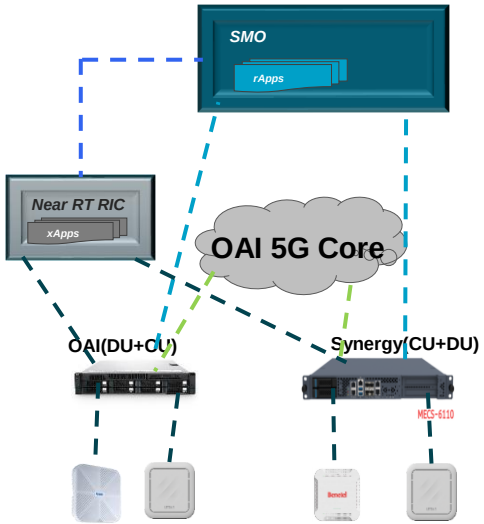
- Design the TeraFactory future network
- Analysis and test of some Open-source Tools
- Choice of a commercial solution for testing and verification

Stage 2



- Network dimensioning and simulation
- Begin rollout (room 3) and measurement campaign, comparison with the simulated results.
- Continuous integration and deployment

Final stage



- Complete the rollout (Room 1,2,4) and integrate new functionalities.
- CI/CD

Summary and next steps

- O-RAN differentiates itself from traditional 5G RAN through its open framework, which reduces reliance on specific manufacturers and enhances hardware and software selection flexibility.
- The economic and technological benefits of O-RAN introduce new challenges and research opportunities.
- Network deployment in the TeraFactory is ready for exploitation and is currently in the evaluation and test stage.
- The existing Testbed belongs to the few that exist and thus offers multiple testing and publication opportunities.
- The rollout is ongoing, and we hope to integrate a MANO controller into the network soon.
- We are currently working on a publication based on the ongoing measurement campaign.
- We plan to build a dataset and start with security and resilience analysis.