



5G NTN E2E Testbed

Integration in the OAI CI Process

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Lasting Software

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Testbench
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Lasting Software

Ongoing/active projects
Projects in preparation

feature development projects

ST Engineering iDirect

- satcom platforms
- technology incubator
- devices products

ALL.SPACE

- feature development

governmental projects

European Protected Waveform

Active member and lead contributor of consortium

IRIS2

Member of the bidding consortium

Other GOVSATCOM

Member of other consortiums bidding for EU governmental projects

LSW Products

CELEOS

Multi-orbit Channel Emulator

FLEX SPACE 5G NTN

5G NTN in-a-box testbed solution
Virtual gNodeB & onboard processing

ESA SPACE Innovation Hub

Hosting ESA Space Innovation Hub in Romania

Lasting Software Products

CELEOS

Multi-orbit Channel Emulator

Emulated Channel Impairments

- delay
- doppler
- attenuation
- noise/interference (AWGN, 5G, DVBX)
- weather

Special Features

- Digital Intermediate Frequency Interoperability (DIFI)
- Signal Metadata Format (SigMF) data recordings
- Two Line Element (TLE) satellite positioning format
- Terminal mobility

FLEX SPACE 5G NTN

5G NTN in-a-box testbed solution

5G NTN E2E integration test environment

- virtualized OAI based CN/gNB/nrUE
- multi-orbit satellite channel emulation
- O-RAN SMO/RIC enabler

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OAI CI overview

- Continuous Integration
- OAI CI Test Pipelines
- OAI CI Testbenches

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5G NTN E2E
Testbench
overview

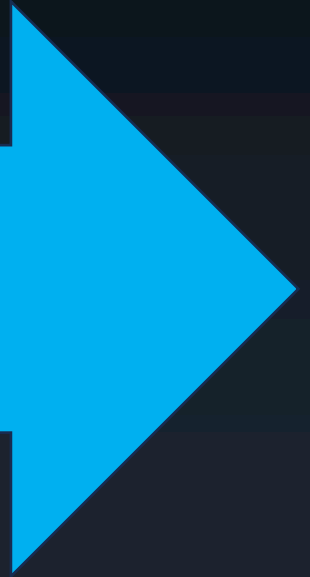
Continuous Integration

Continuous Integration (CI) steps

CI server pulls
latest changes

New
binaries creation

***Automated
testing***



Test Pipeline

Automated testing step definition

(Binary files + Test suite) / Test bench

OAI CI Overview

5G Test Pipelines

- **RAN-PhySim-Cluster** (OpenShift, unitary simulators)
- **RAN-L2-Sim-Test-5G** (L2simulator, no physical layer)
- **RAN-RF-Sim-Test-5G** (RFsimulator, TDD 40MHz, FDD 40MHz, F1 split)
- **OAI-CN5G-COTS-UE-Test** (Attach/Detach, multiple PDU sessions)
- **RAN-Interop-F1** (Accelleran CU, OAI DU)
- **RAN-NSA-B200-Module-LTEBOX-Container** (basic NSA tests)
- **RAN-SA-B200-Module-SABOX-Container** (basic SA test, 20 MHz TDD)
- **RAN-SA-AW2S-CN5G** (Amarisoft UE)
- **RAN-SA-OAIUE-CN5G** (OAIUE, gNB running on containers)
- **RAN-gNB-N300-Timing-Phytest-LDPC** (performance test)
- **RAN-SA-AERIAL-CN5G** (OAI VNF + PNF/NVIDIA CUBB on Aerial2)

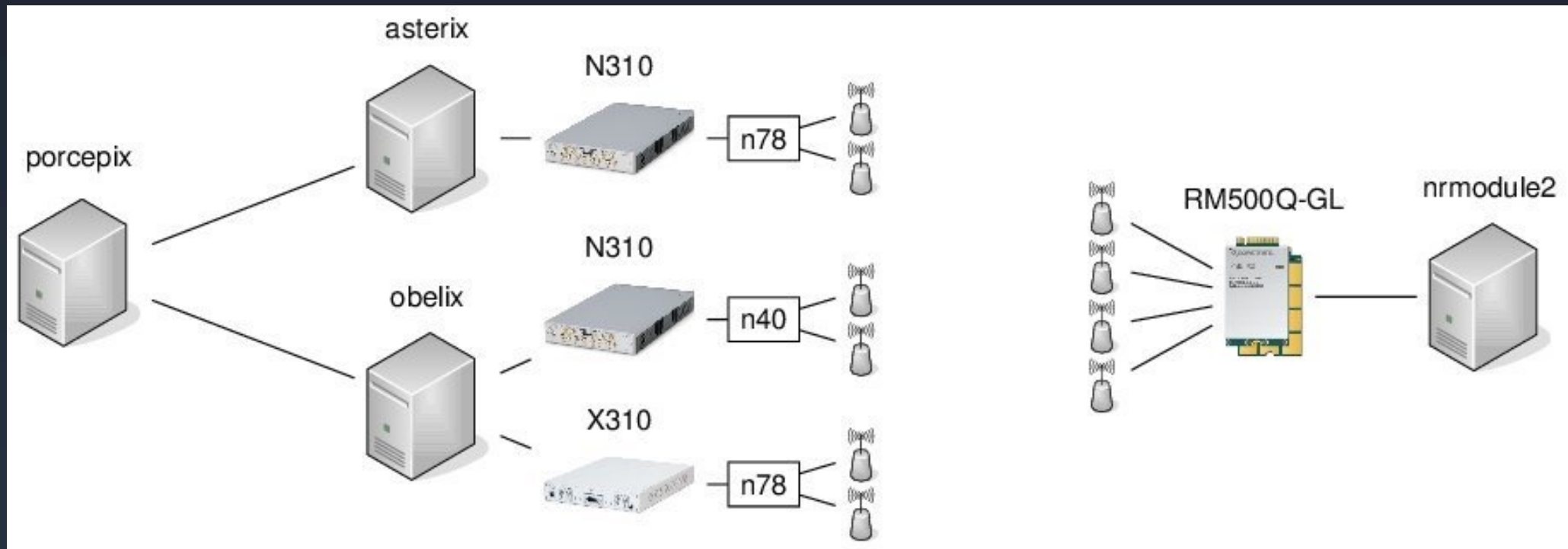
OAI CI Overview

5G Test Benches

- 5G OTA Testbench
- 5G NSA/Faraday Cage Testbench
- 5G AW2S Testbench
- 5G UE OTA Testbench

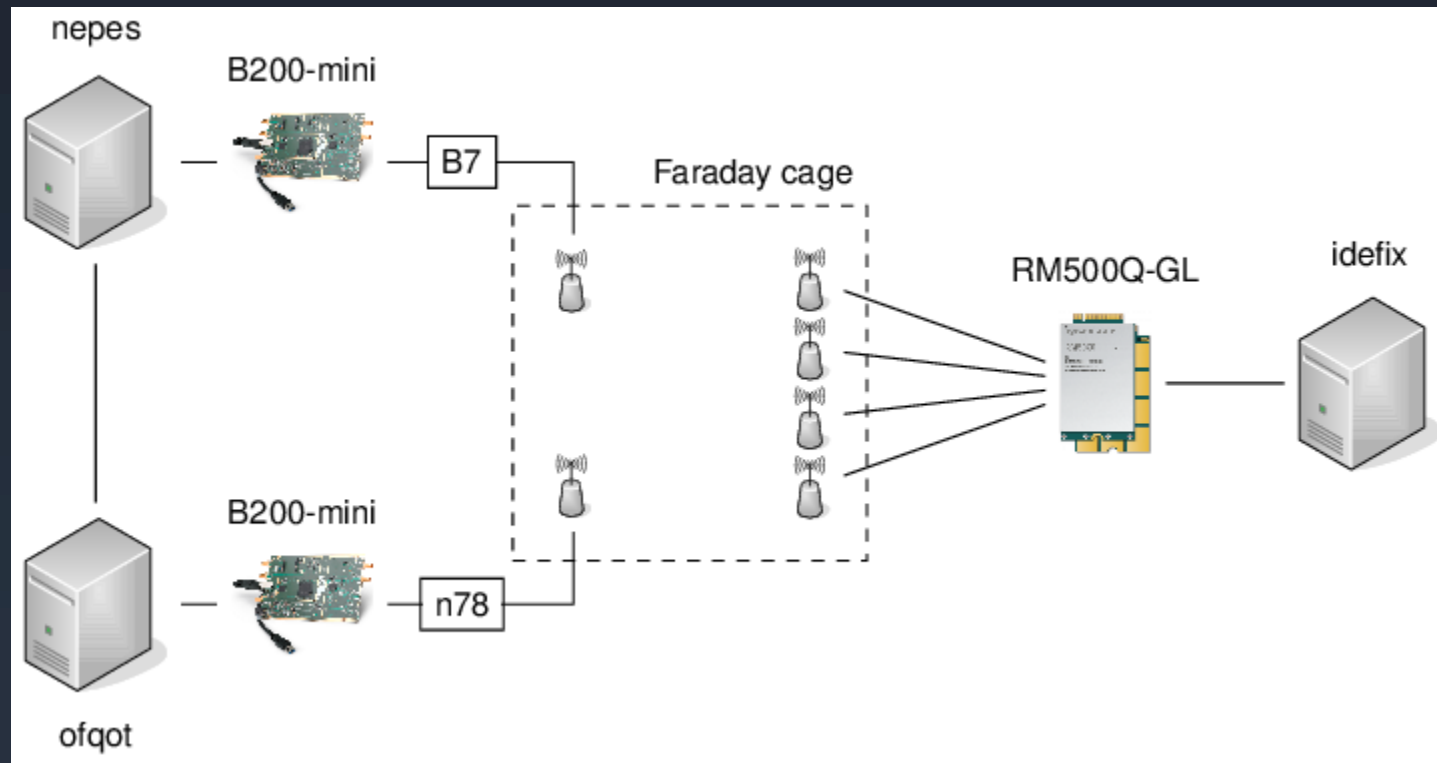
5G OTA Testbench

Purpose: Over-the-air 5G SA tests, performance tests



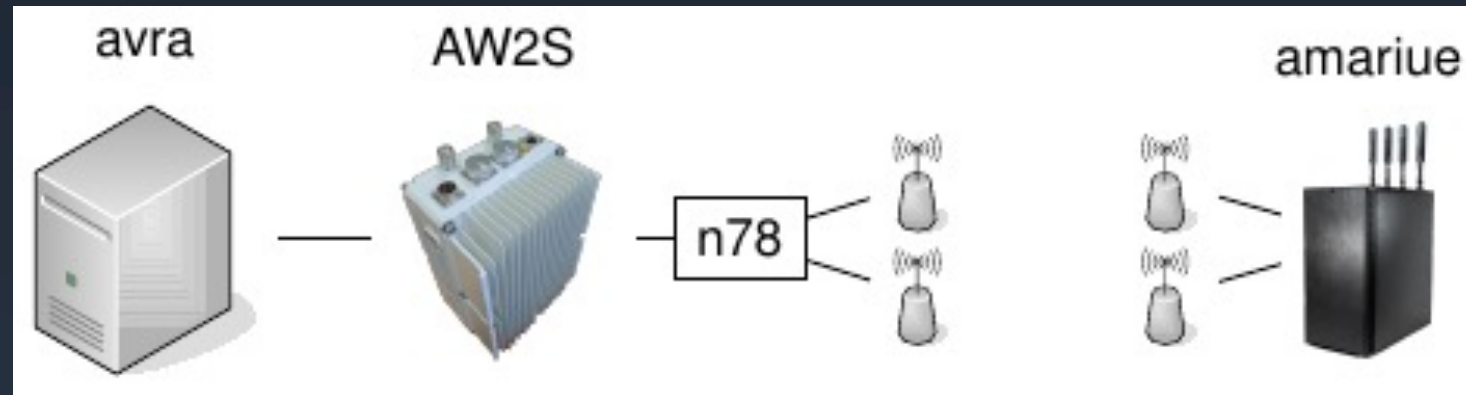
5G NSA/Faraday Cage Testbench

Purpose: Faraday cage 5G tests, functional tests



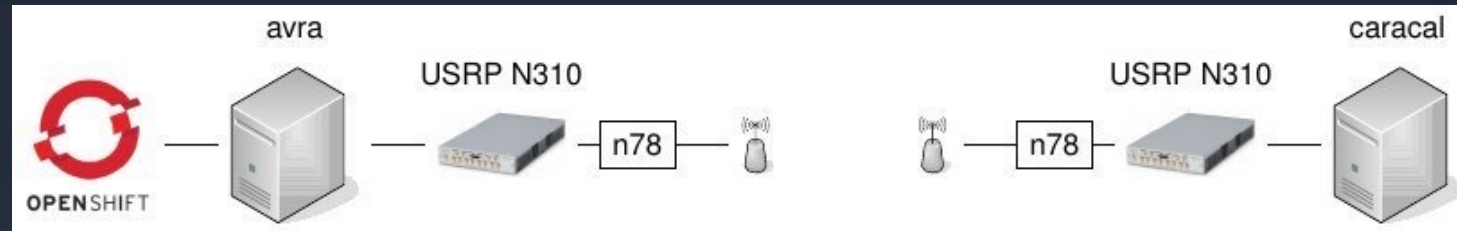
5G AW2S Testbench

Purpose: AW2S tests with Amarisoft UE simulator



5G UE OTA Testbench

Purpose: Over-the-air 5G tests with OAI UE



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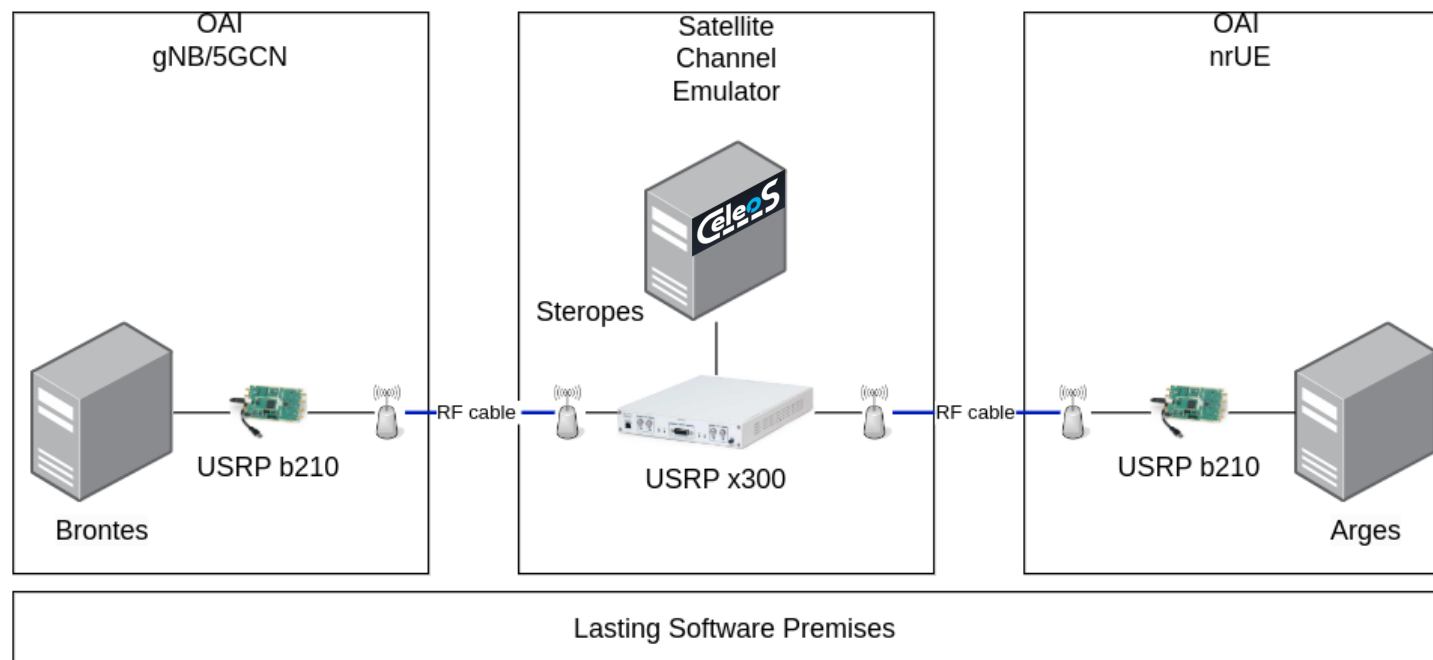
5G NTN E2E Testbench overview

- CELEOS Multi-orbit Satellite Channel Emulator
- 5G NTN E2E Test Pipeline
- 5G NTN E2E Testbench Evolution(s)

5G NTN E2E Testbench

Purpose: RF Test Cable 5G NTN tests with OAI UE

New



CELEOS

Multi-orbit satellite channel emulator - Impairments

Delay

- Constant and variable delay support
- Variation rate supports the most challenging mobility use cases e.g. LEO
- Min: 2ms
- Max: 1000ms

Path attenuation

- Constant and variable attenuation support
- Variation rate supports the most challenging mobility use cases e.g. LEO
- Range: 0dB to 70dB

Noise/Interference

- AWGN and 5G/DVB-S2X interference support
- Two type of configurations:
 - fixed power
 - Specific SNR target level
- Custom noise could be added on request

Weather effects

- Attenuation and phase change due to the atmospheric conditions support
- Clear sky
- Rain
- Heavy rain

Doppler shift

- The most challenging scenario support: LEO in Ka band

Phase noise

- Support of random changes to signal phase, configurable severity

Doppler spread

- Rayleigh distribution support for non-line-of-sight path

Satellite amplifier non-linearity

- Two amplifier model support:
 - Traveling wave tube amplifier
 - Solid-state power amplifier.

Customer Specific Development

Impairments or features

Examples:

- RF antenna misalignment related to ground or satellite
- specific impairments: e.g. GEO in-box movement, helicopter

CELEOS

Multi-orbit satellite channel emulator - Special features support

DIFI

- Digital Intermediate Frequency Interoperability protocol I/O (input/output)
- RF conversion to DIFI
- DIFI conversion to RF

SigMF

- SigMF data recordings
- Recording of I/O as SigMF
- Import and export of recordings
- Conversion from RF/DIFI to SigMF and SigMF to RF/DIFI

TLE

- Two Line Element satellite positioning format
- Automatic configuration based on TLE file: LEO/MEO/GEO
- Channel emulation depending on the satellite position, speed, and trajectory in time

Terminal mobility

- Configuration of static and moving terminals together with moving satellite (TLE)
- Possibility to integrate with navigation database (maps)

CELEOS in 5G NTN E2E Testbench

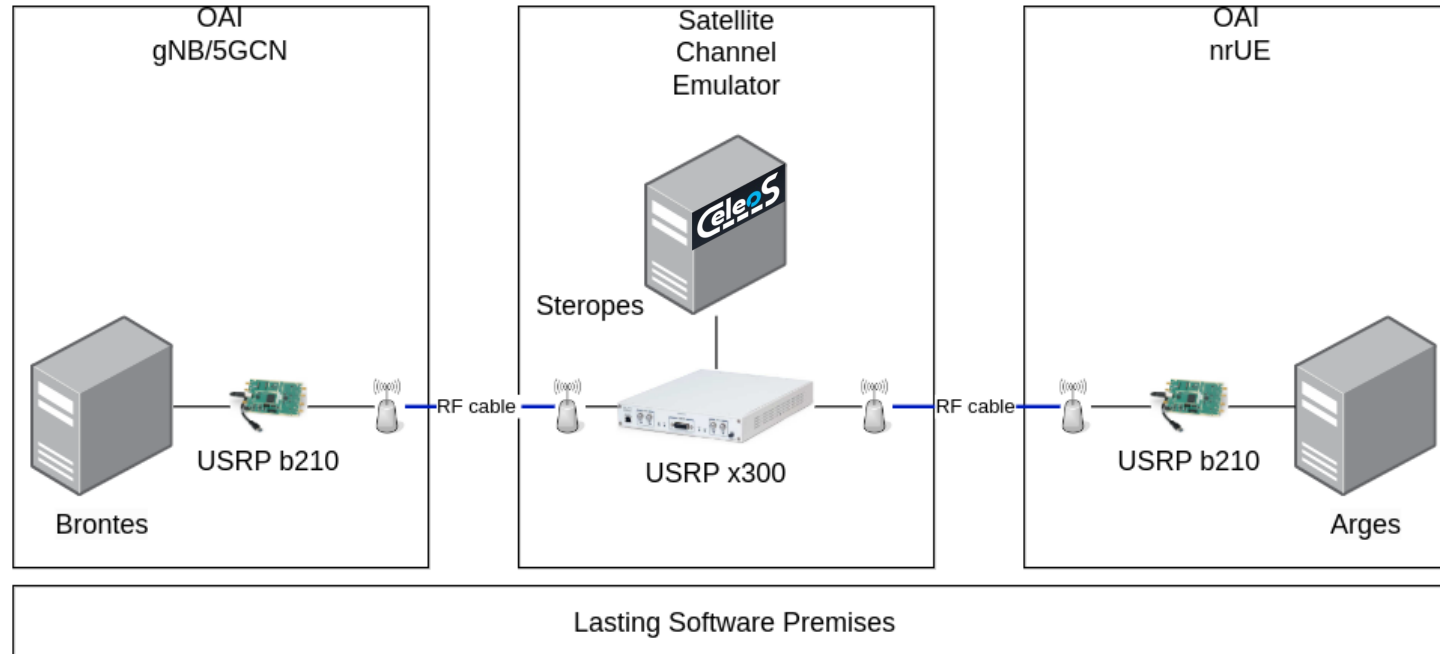
Multi-orbit satellite channel emulator - Setup options

- Orbit type (LEO / GEO)
- Uplink frequency band (S / C / Ku / Ka), downlink frequency band (S / C / Ku / Ka)
- Rx and Tx central frequencies
- Bandwidth 5/10/?? MHz
- Pre-defined noise profile (enabled or disabled)
- In-box movement (enabled or disabled, only for GEO orbit type)

5G NTN E2E Testbench

Purpose: RF Test Cable 5G NTN tests with OAI UE

New



5G NTN E2E Test Pipeline

Using 5G NTN E2E Testbench



New

Use binaries from *leo-5g-ntn* branch (initially) and/or from develop branch (when NTN support is merged)

- **CELEOS** channel emulator custom development to orchestrate interaction with UE (initial attach)

Automated Tests

- UE Attach
- Ping
- UDP uplink/downlink traffic using Iperf

5G NTN E2E Testbench

UDP encapsulated IQ samples

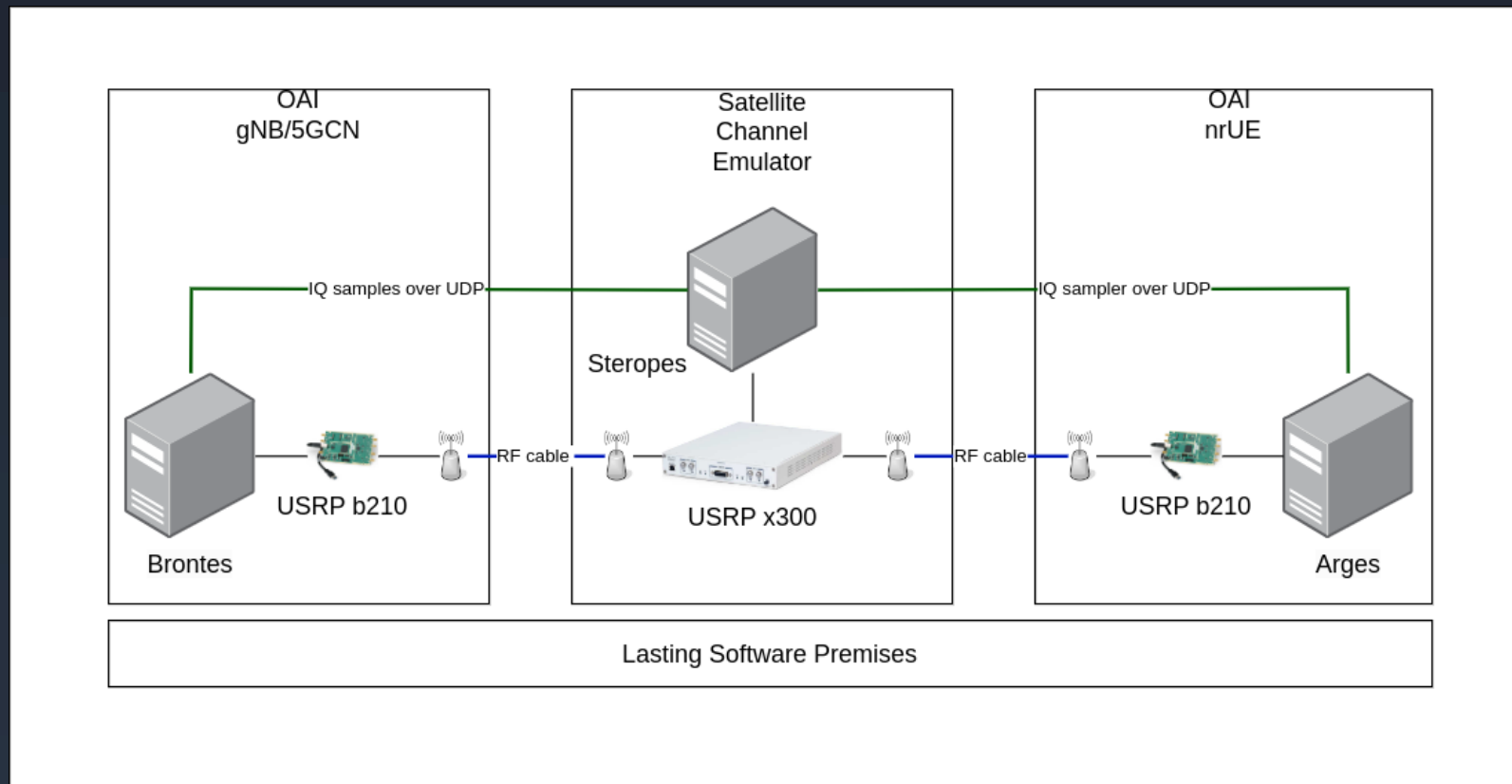
A blue starburst graphic with the word "Evolution" inside it.

Evolution

- Use **UDP encapsulated of IQ Samples** between gNB/UE and **CELEOS** Channel Emulator (instead of USRP SDRs)
- **Easier to scale** without dependency to USRP SDR (BW/number of channels)
- **Running E2E NTN 5G simulation on development workstations** (intermediate step)
- **DIF1 integration** enabler

5G NTN E2E Testbench

UDP encapsulated IQ samples



Evolution

5G NTN E2E Testbench

Virtualized E2E NTN 5G simulation

- **Run all components (gNB/UE/Channel Emulator) on virtualized environment**
 - Using UDP encapsulated IQ samples
 - Based on virtualized **CELEOS** satellite channel emulator
- **Provide images to run virtualized E2E NTN 5G simulation on development workstations**



Evolution

5G NTN E2E Testbench

Take aways

- **CELEOS/OAI 5G NTN E2E Testbench can be used to validate OAI 5G NTN non-regression/smoke tests or basic scenarios**
- **CELEOS multi-orbit Satellite Channel Emulator for various use cases:**
 - Virtualization
 - UDP Encapsulation/DIFI
 - Custom Channel Impairments
- **Virtualization and IQ Samples over UDP enables E2E NTN 5G simulation on development workstations**

Thank you!



La^{sting}
software