GRADUATE SCHOOL AND RESEARCH CENTER AT THE HEART OF THE DIGITAL SOCIETY

EURECOM
Sophia Antipolis

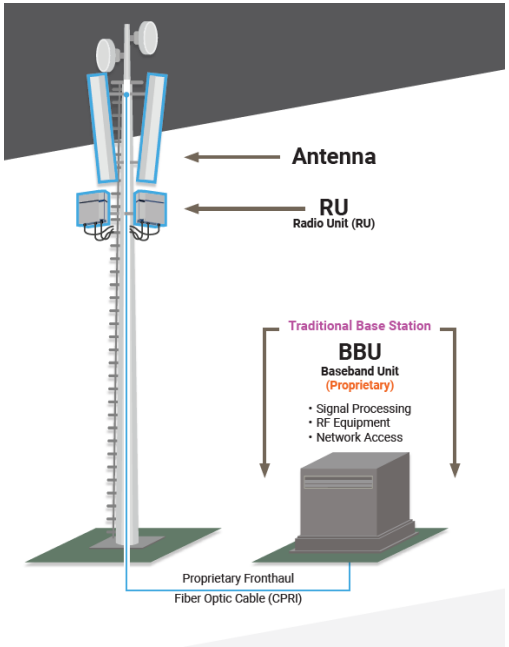
OPEN AIR INTERFACE

Democratizing innovation in the 5G era

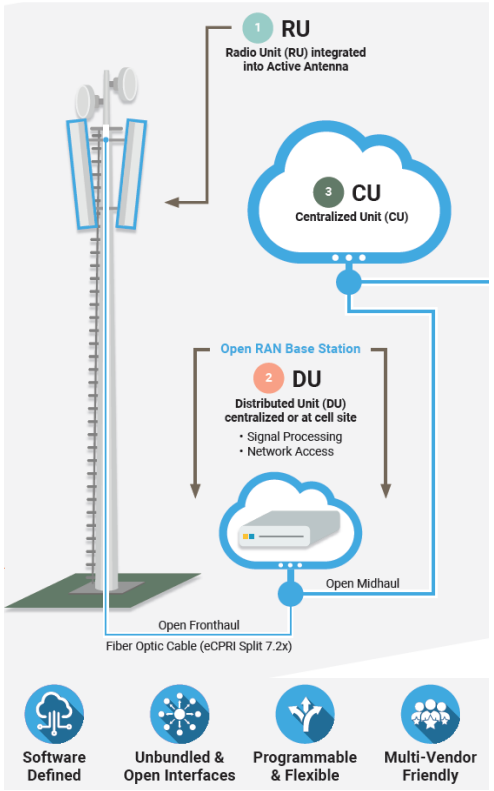
Florian Kaltenberger (Eurecom)

Colloque IMT : Réseaux du futur, 14.10.2021

Traditional RAN → Open RAN



Source: open RAN policy coalition



Open RAN ≠ Open Source

- But combination of both is a powerful tool to build **sovereign networks**
- **OpenAirInterface** (OAI) is the **most complete, open-source** implementation of 3GPP 4G/5G RAN and EPC/5GC
- Other types of open-source software
  - ORAN OSC (partially open-source RAN, 3GPP-friendly licensing)
  - srsLTE/srsRAN (4G/5G RAN, OSI licensing)
  - OMEC (EPC, OSI Licensing)
  - Magma (EPC/5GC, OSI Licensing)
  - Free5gc (5GC, OSI Licensing)
  - Open5gs (EPC/5GC, OSI Licensing)

The OpenAirInterface Software Alliance

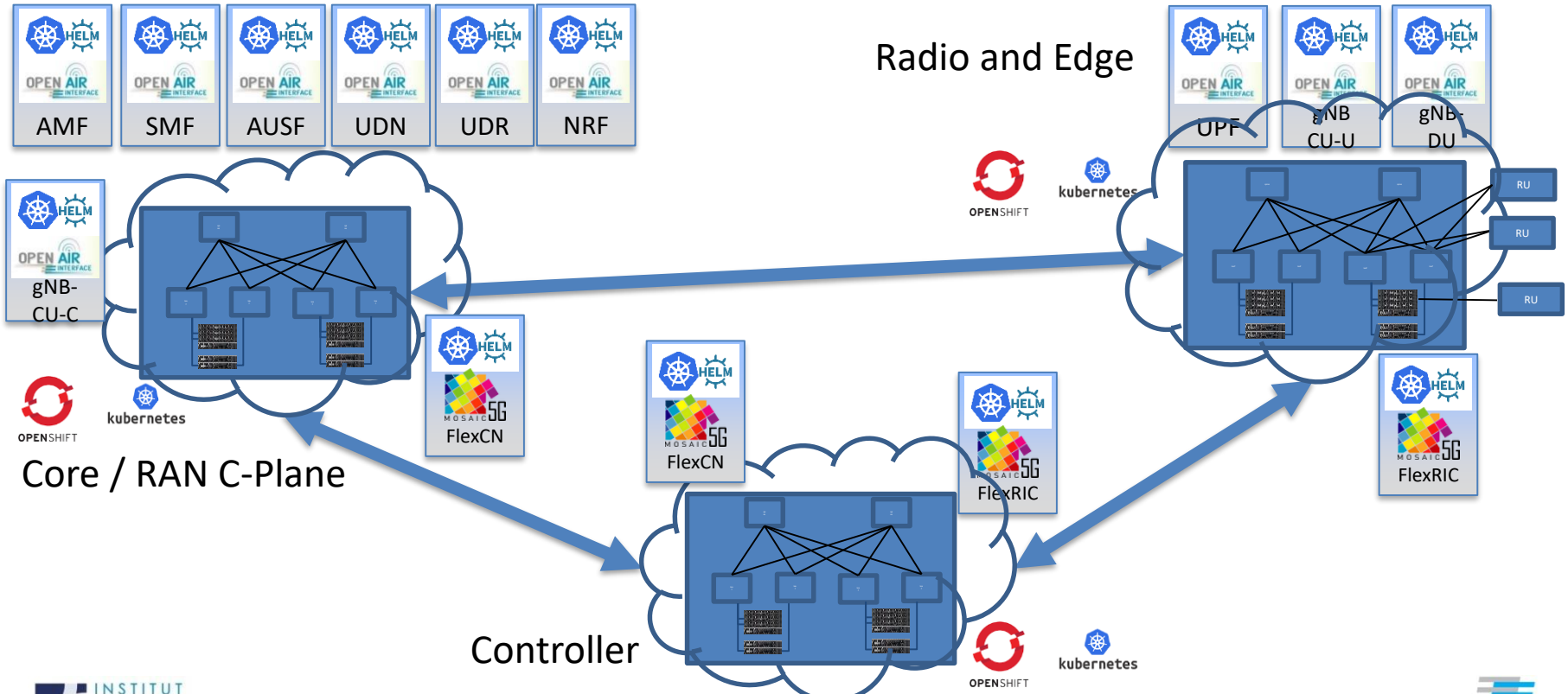
- Launched in 2014 as an endowment fund (French “Fonds de Dotation”)
- Current strategic members

- Many associate members
- Goals:
  - Promote OpenAirInterface and its open-source licensing model
  - Support the community of developers and users
  - Accept donations to maintain engineering support team

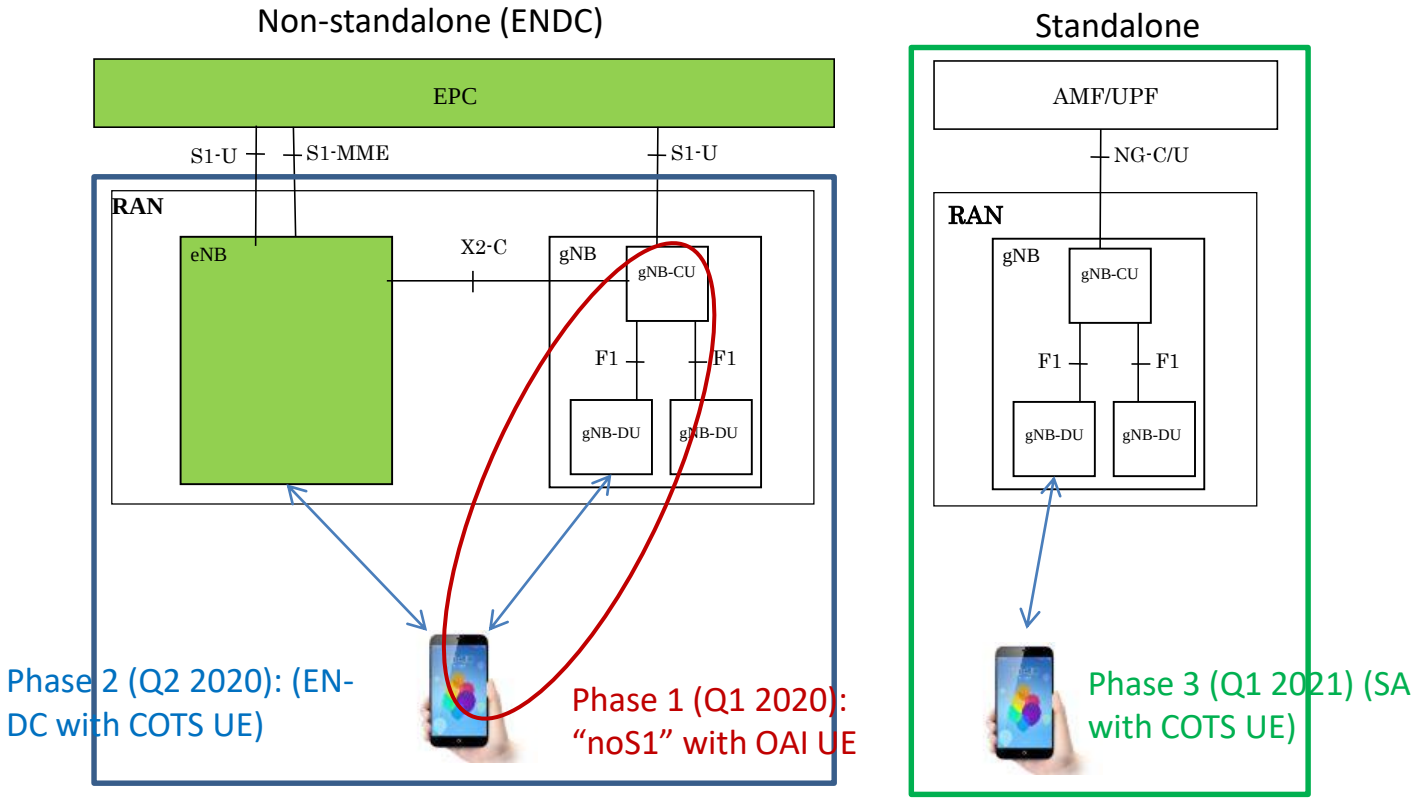
Project Groups

- OAI Public License Components
  - 4G / 5G RAN : eNB/gNB/UE L1/L2 Network functions, RF modeling
  - 5G Core : 3GPP Service-Based Architecture Network functions
  - Mosaic5G : RAN and Core Controller functions, Orchestration and Management
- 3-Clause BSD Components
  - Rel16 MME (4G/5G NSA) as part of Magma Foundation

OAI cloud native deployment



OAI 5G deployment options



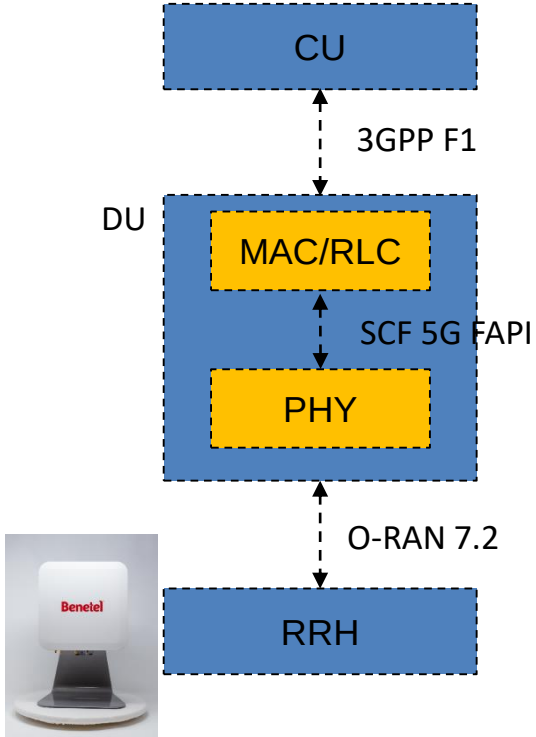
OAI supported hardware platforms

- Tested RRUs
  - USRP B210, X310, and N310 (for LTE and NR)
  - Benetel RRU (NSA bands 7 and n78 only): O-RAN 7.2 split
  - AW2S (LTE and NR): eCPRI
- Tested UEs
  - Oppo Reno 5G
  - Samsung A90 5G
  - Samsung A42 5G
  - Google Pixel 5G
  - Simcom SIMCOM8200EA
  - Quectel RM500Q-GL
  - Huawei Mate 30

NSA only

SA & NSA

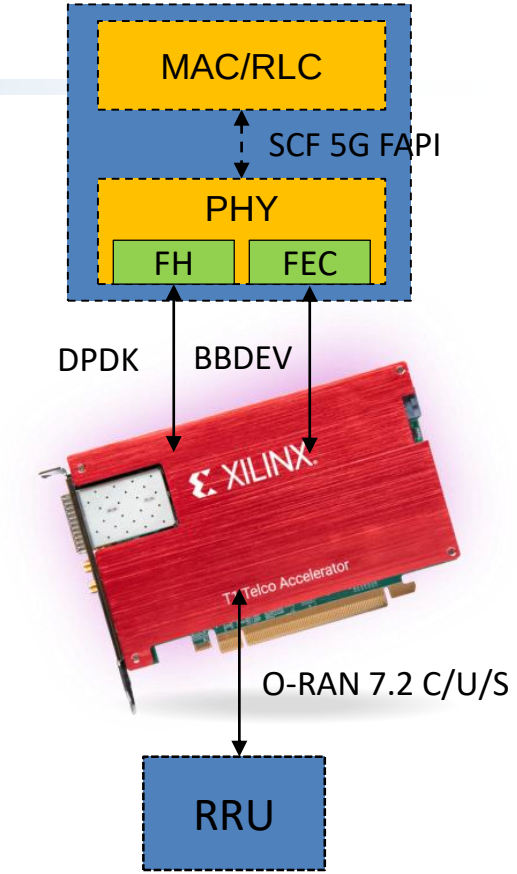
Functional splits in OAI 4G/5G



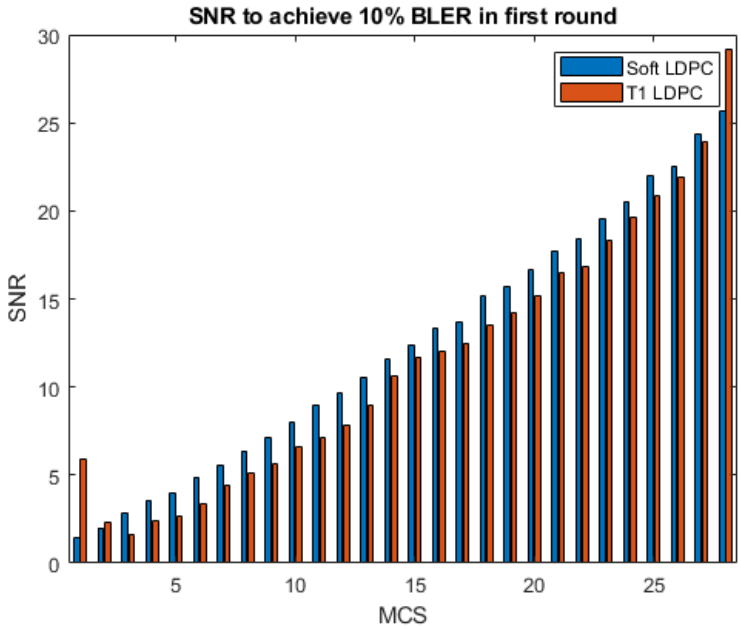
- F1-C and F1-U
  - Revised implementation under integration
  - Interoperability testing with Acceleran ongoing
- 5G FAPI
  - today all L1 procedures compliant with SCF 5G FAPI
  - 5G nFAPI
- Fronthaul
  - O-RAN 7.2 U-plane done (with Benetel)
  - Interoperability with other RRUs planned for 2H 2021
  - Integration of Xilinx T1 card

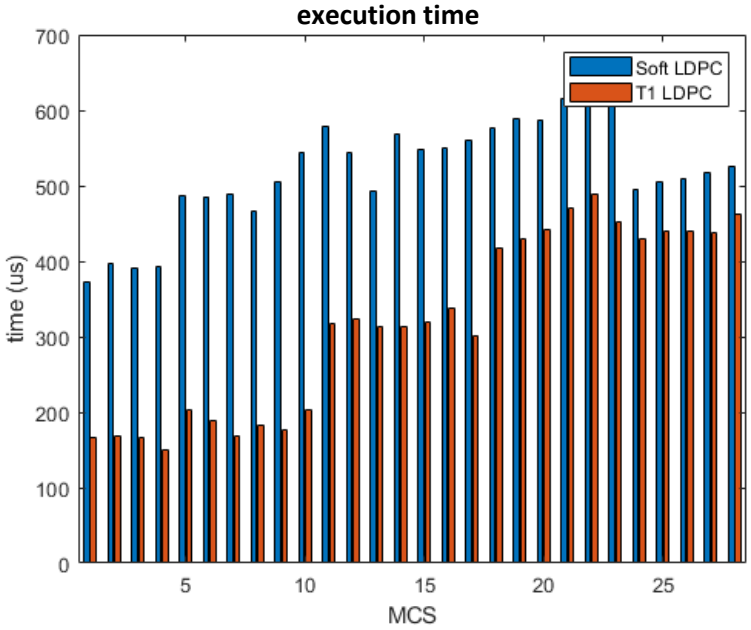
T1 LDPC Offload

- Channel coding/decoding consumes most energy/processing time
  - 91% of total RX processing time in OAI
- Xilinx T1 accelerator card
  - Contains ZU19EG MPSoC and ZU21DR RFSoC
  - Offload of forward error correction and fronthaul
  - Bitstream and drivers provided by VVDN
- LDPC channel decoding integrated in OAI
  - Works with nr_ulsim and nr-softmodem



T1 LDPC Offload



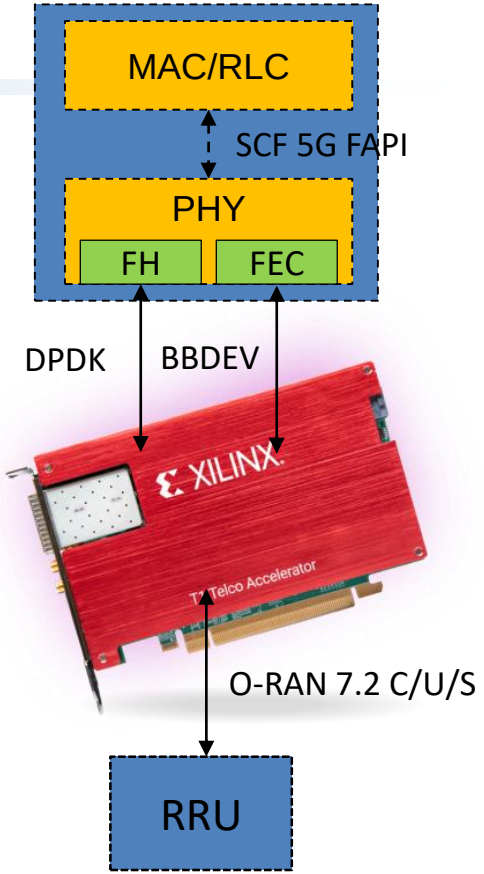


NR-PUSCH, SCS 30kHz, 106PRB, 12OFDM symbols, 1 DRMS, SISO, TDL-C channel

Florian Kaltenberger, Hongzhi Wang, Saktivel Velumani, “Performance evaluation of offloading LDPC decoding to an FPGA in 5G baseband processing,” Workshop on Smart Antennas (WSA2021), Sophia-Antipolis, France, 10-12.11.2021.

T1 Fronthaul

- Xilinx T1 accelerator card
  - Contains ZU19EG MPSoC and ZU21DR RFSoC
  - Offload of forward error correction and fronthaul
- Goal2: use card for O-RAN 7.2 fronthaul offload
  - Need O-RU for testing



Roadmap 2021

- Stabilize X2 and S1 procedures in NSA
  - To recover from errors on 4G or 5G link failures
- Improve throughput
  - Target1: 100/400Mbps DL, 30Mpbs UL (SISO/MIMO 106 PRB) (USRPs)
  - Target2: 200/800Mbps DL, 60Mpbs UL (SISO/MIMO 273 PRB) (high-end RRU)
- Link adaptation based on CQI (incl MIMO)
- Basic NSA FR2 interoperability
  - Including beamforming procedures
  - Ongoing, debugging initial access procedure
- DL MIMO support (4x4)
  - Including CSI RS and feedback reporting
- Support for flexible bandwidth and subcarrier spacing
  - 60kHz SCS (Also requires multiplexing multiple SCS)
  - 10/20/40/50/60/80/100 MHz bandwidth part
  - Support for multiple bandwidth parts
- SDAP support
- F1AP integration with commercial CU solution (Accelleran)

Roadmap 2022

- Integration of TTCN-3 interfaces in eNB and gNB
  - All software conformance testing of UE protocol stack (Sequans, Firecell)
- E1AP and CU-C/U separation
- Support for localization (Rel 16)
- SA specific
  - Support for FR2
  - Handover Procedures (Xn)
  - Support for Non-terrestrial networks (Rel 17)
- Support O-RAN 7.2 fronthaul
  - Control and user plane
  - Using T1 card and commercial RRU
- Support O-RAN interfaces (E1, O1)

THANK YOU

Status of 5G NSA development

- Non-standalone EN-DC with COTS phones since August 2020
  - FR1, static TDD (5ms, 7-1-2), 30kHz subcarrier spacing, 106PRB (40MHz), SISO
  - No split bearer, traffic is redirected to 5G cell
- Current performance
  - 80Mbps DL throughput (with 64QAM)
  - 7Mbps UL throughput (with QPSK, to be improved)
  - Up to 2 users tested
- Tested Core networks
  - OAI EPC
  - Nokia LTEbox

Status of 5G SA development

- First complete attach: 4th May 2021
- First DL and UL user-plane traffic (ping): 18th May 2021
- Same PHY configuration as NSA
- Current performance:
  - Latency: 9ms (mean)
  - Stability: up to 1h (without pushing traffic too much)
  - 20Mbps max DL throughput (with 64QAM, to be improved)
  - 7Mbps max UL throughput (with QPSK, to be improved)
- Some regressions were introduced in current develop (Sept 2021)
  - Fixes on the way
- Some CI tests are broken/incomplete
  - Issues with USRP N310 and UHD 4.x
- Validated Core networks
  - OAI 5GC and
  - Nokia Sabox
  - Free CN

Additions for SA

- CORESET0, SIB1, initial BWP
- Contention based initial access
  - Retransmissions of msg3/msg4
- RRC:
  - RRCSetup[Complete]
  - SecurityMode[Command|Complete]
  - UECapability[Request|Indication]
  - RRCReconfiguration[Complete]
    - Done in multiple steps
  - [DL|UL]InformationTransfer
    - Integration with NAS
- RLC: Handling of SRB0, SRB1, DRB
- PDCP: security (integrity)
- NGAP: connection to AMF
- GTPU: connection to UPF

SA UE

- Supporting "noS1" mode (DL and UL):
  - Creates TUN interface to PDCP to inject and receive user-place traffic
  - No connection to the core network
- Supporting Standalone (SA) mode:
  - UE can register with the 5G Core Network, establish a PDU Session and exchange user-plane traffic

FR1 MIMO status

- In develop branch
  - PHY layer support (gNB and UE) for 4x4 antennas and 2 layers max.
  - Validated in simulation and over-the-air using phy-test mode
  - Transmission of CSI-RS
- Ongoing developments/testing
  - Make Precoder matrices standard-compliant and integrate with SCF FAPI interface
  - MAC procedures to analyze and apply the CSI report in terms of CQI and RI, for MCS and nb of layers
- Todo
  - UE: CSI-RS receiver and CSI report

FR2 NSA status

- Basic development of PHY & MAC for FR2 done
  - 120kHz subcarrier spacing
  - Beamforming support (using GPIO to control external RF)
  - Transmission of multiple SSBs
  - Support for multiple PRACH occasions for initial beam correspondence.
- Tests with OAI gNB + OAI UE ok
  - Using intermediate frequency ~5GHz
  - Real-time operation ok
  - Initial beam selection ok
- Interoperability with COTS phone: not yet
  - Phone not even seeing 5G cell during inter-RAT measurements

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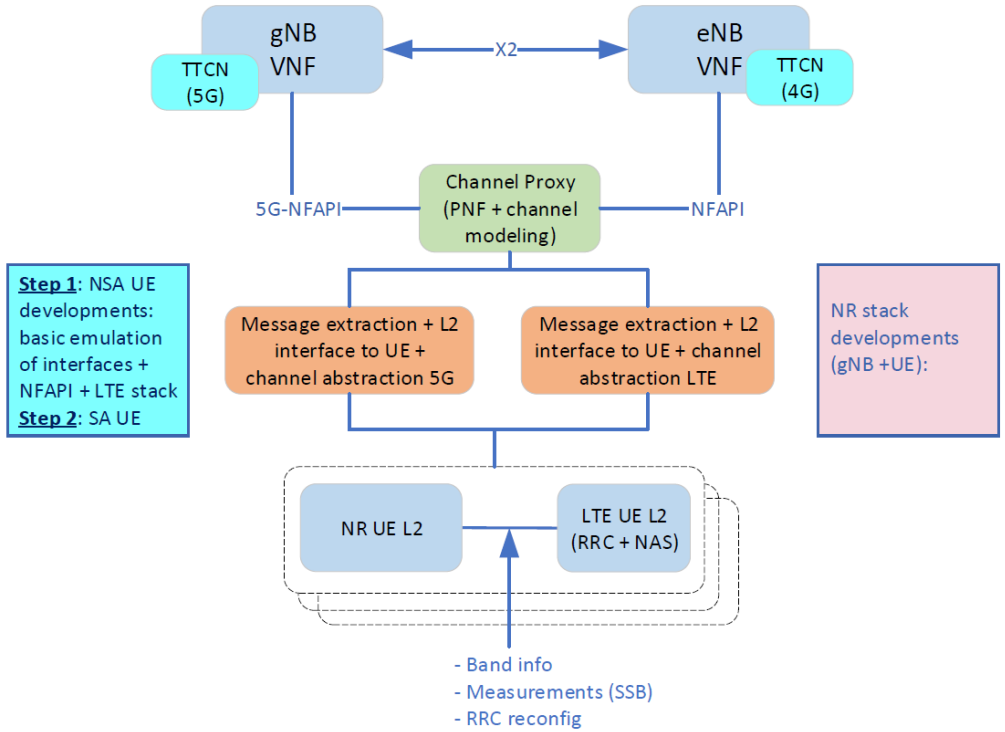
L2 emulator for NSA

- Uses 4G and (new) 5G nFAPI
- Includes NSA UE
  - That can be re-used also with USRP
- Same framework used for TTCN-3 project
  - Using Sequans UE stack
- Under integration in develop



Status of 5G NTN developments

- Rel15 and Rel16 features necessary for NTN already part of public OAI repository
  - FDD support
  - Multiple DMRS support
  - 10MHz bandwidth support
- Initial development based on Rel17 drafts started by Fraunhofer IIS
  - Extension of time domain allocation (k2) for PUSCH scheduled by RAR UL grant
  - Extension of time domain allocation (k2) for PUSCH scheduled by DCI
  - Extension of RAR window
  - Disabling of HARQ