A BRIEF INTRODUCTION TO O-RAN

Towards Intelligent and Interoperable Radio Access Networks

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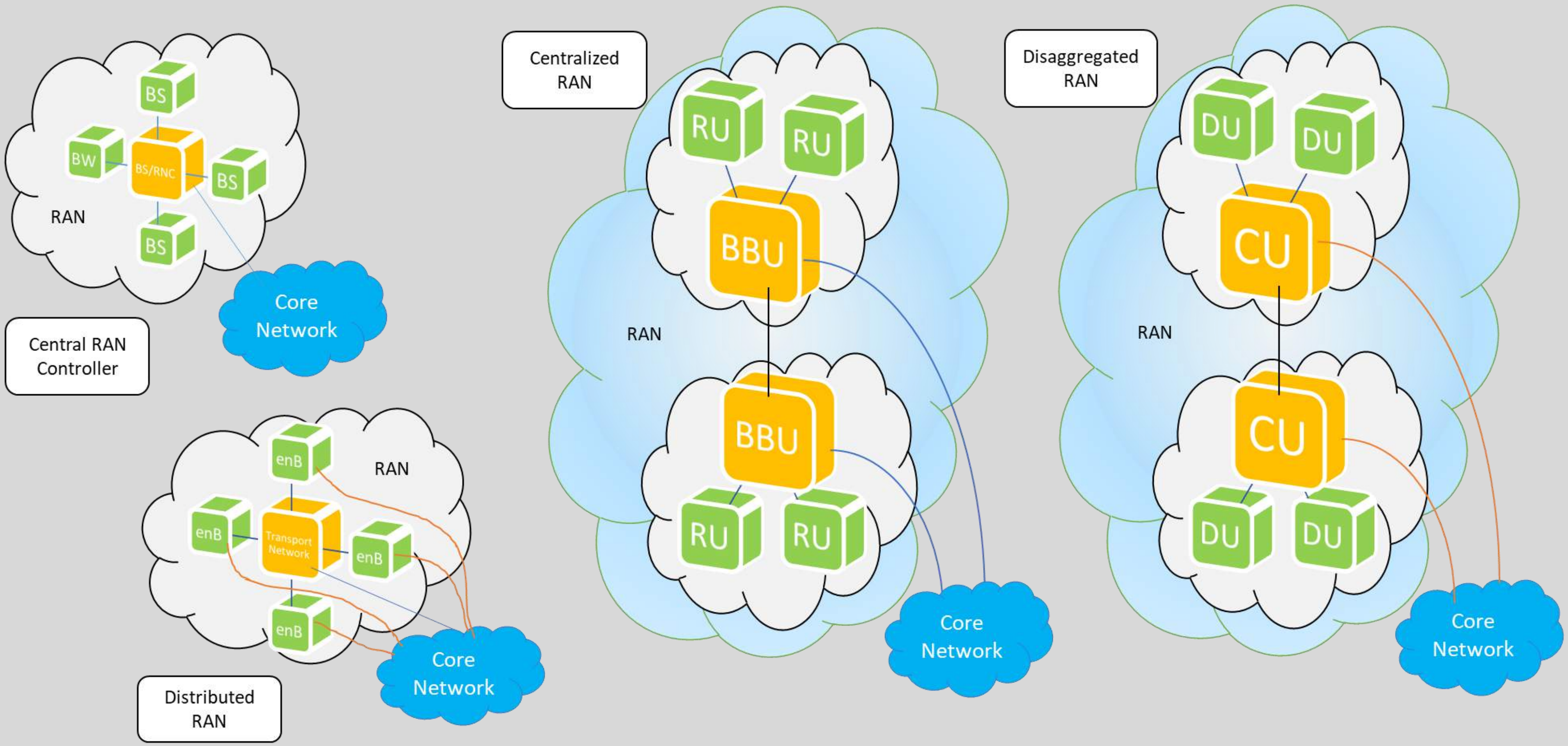
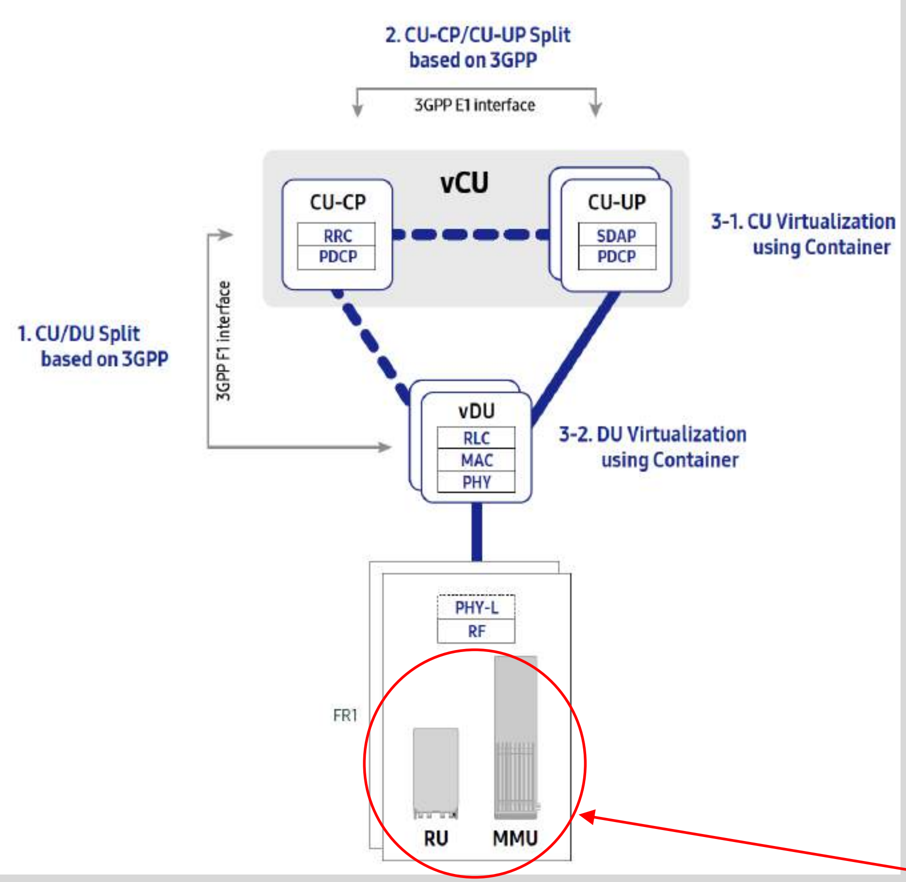
Evolution of RAN Deployments Through the Years

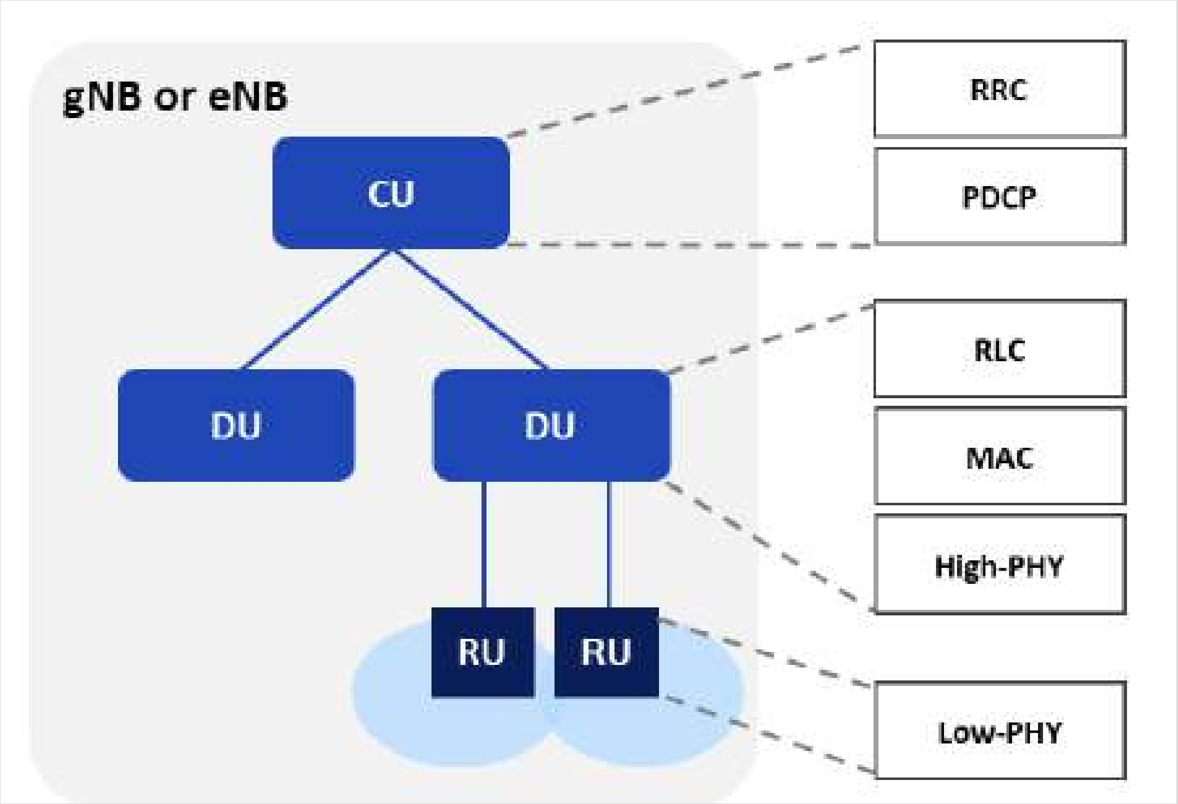


Acknowledgment. Borrowed from Nishith D. Tripathi and Vijay K. Shah, "Fundamentals of O-RAN," Book accepted for publication by Wiley.

Disaggregated gNB: Samsung

The disaggregated architecture can be virtualized.





Samsung customization!

MMU: Massive MIMO Unit
RU: Radio Unit

Reference: Samsung, "Virtualized Radio Access Network,"
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What is O-RAN?

- O-RAN: Open-Radio Access Network (O-RAN)
- A comprehensive framework for implementing AI-driven & interoperable Radio Access Network (RAN).
- A cellular network has a RAN, a core network, and a services network ("IP Multimedia Subsystem (IMS)").
- Currently supported technologies: Fourth-Generation (4G) Long-Term Evolution (LTE) and Fifth-Generation (5G).

Benefits:

- Expand vendor ecosystem
- Reduce CAPEX by increasing competition.
- Create new use cases and business opportunities

Risks:

- Complex system. System integration
- Network performance evaluation.
- Difficult operation and maintenance
- Distributed accountability.

Key Aspects of O-RAN

- **Openness:**
  - Open/standardized interfaces
  - Open-source software
  - White box or generic hardware, often called Commercial-Off-The-Shelf (COTS) hardware
- **Intelligence:**
  - Manage the RAN (e.g., dynamic radio resource management)
  - Autonomous RAN with AI learning
  - Embedded intelligence through RAN Intelligent Controllers (RICs)

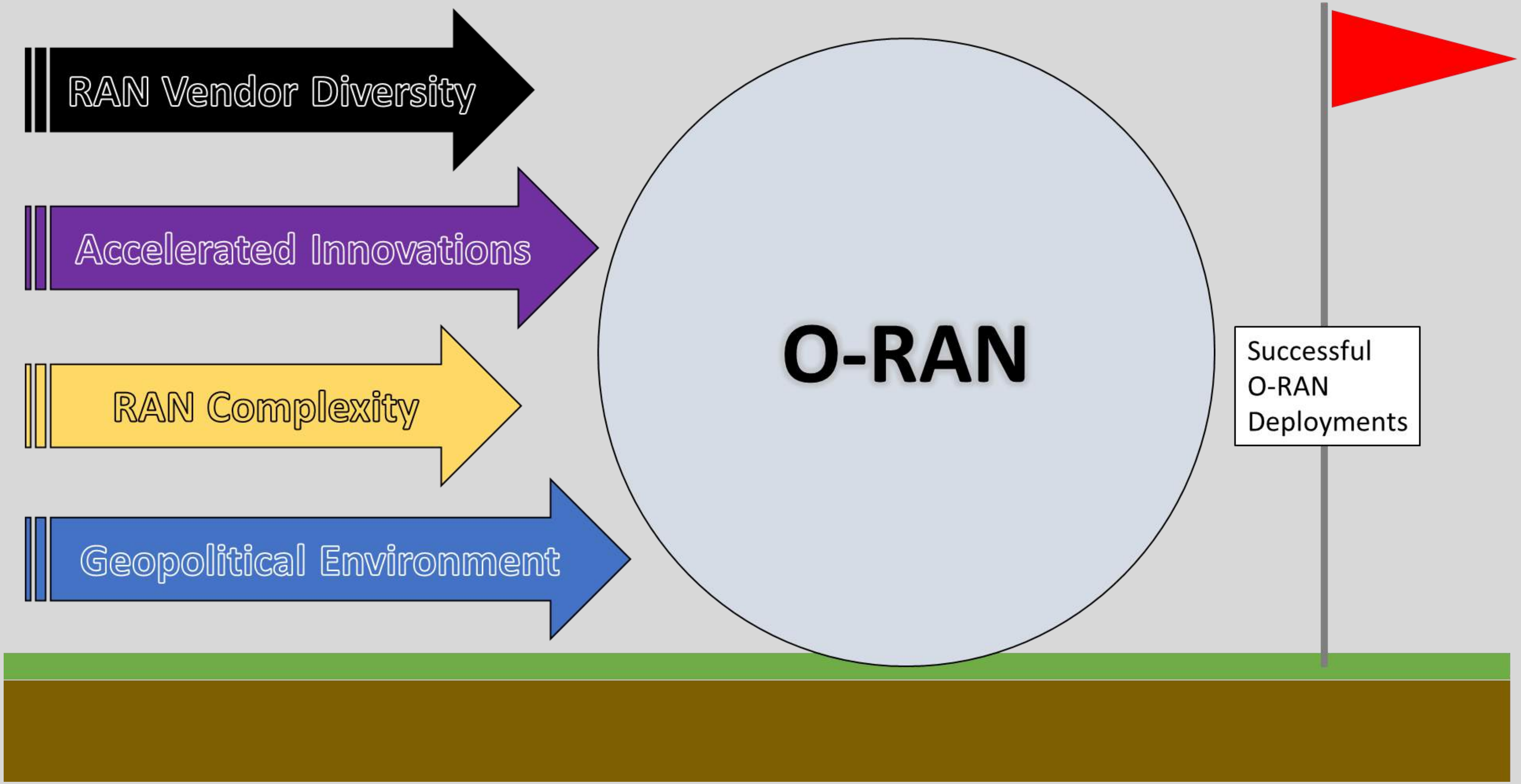
About O-RAN Alliance

- The O-RAN specifications are developed by the O-RAN Alliance just like 4G and 5G specifications have been developed by the Third-Generation Partnership Project (3GPP).
- The O-RAN Alliance was founded in February 2018 by AT&T, China Mobile, Deutsche Telekom, NTT DOCOMO, and Orange.
- It was established as a German entity in August 2018.
- Today's O-RAN Alliance is a global community of mobile network operators (MNOs), vendors, and research and academic institutions.
- Mission of the O-RAN Alliance: "Re-shape the RAN industry towards more intelligent, open, virtualized and fully interoperable mobile networks".
- O-RAN specifications can be augmented to support future cellular technologies.

O-RAN ALLIANCE

Reference: https://www.o-ran.org/about

Driving Forces Behind O-RAN



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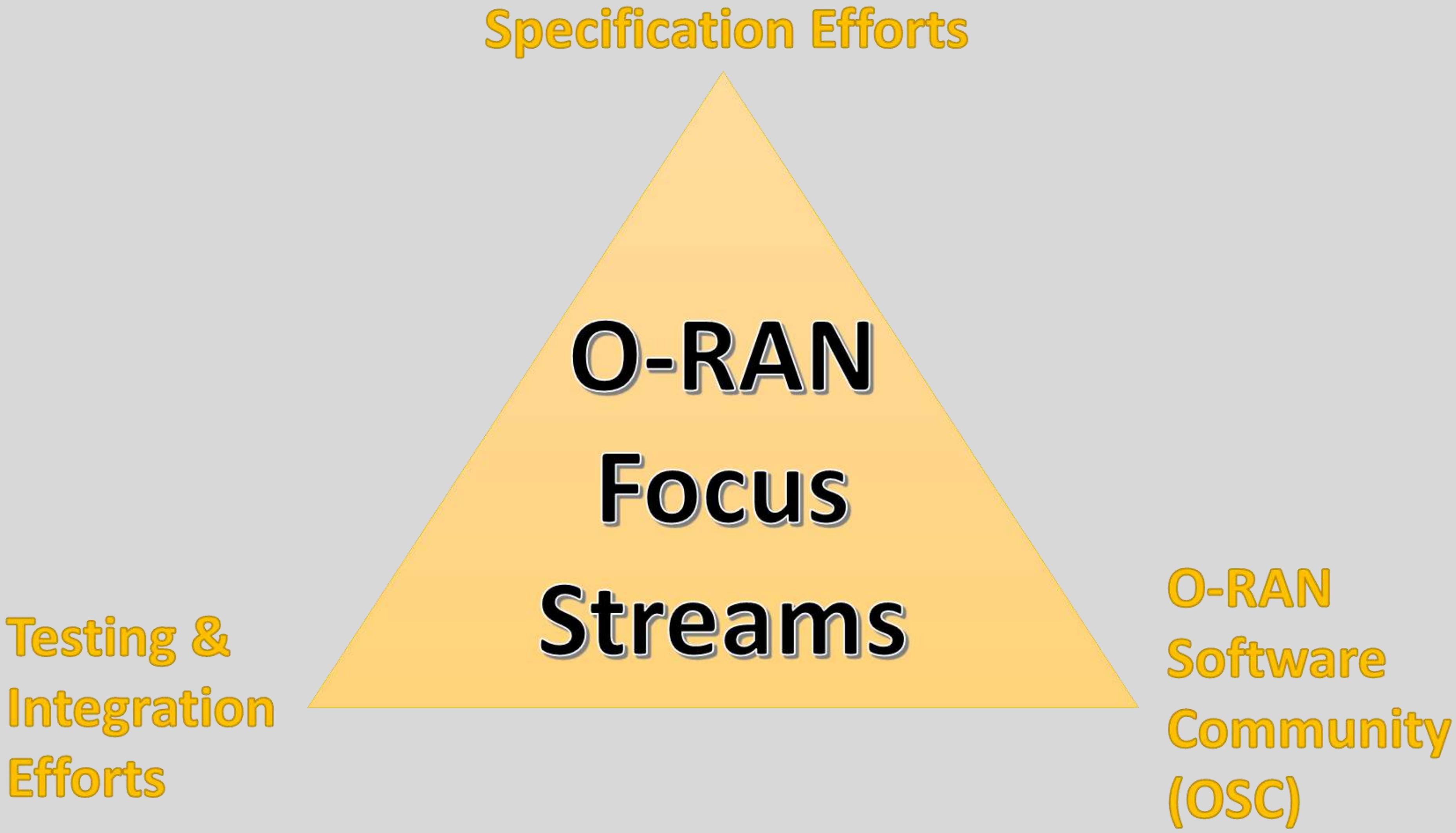
O-RAN Alliance Responsibilities



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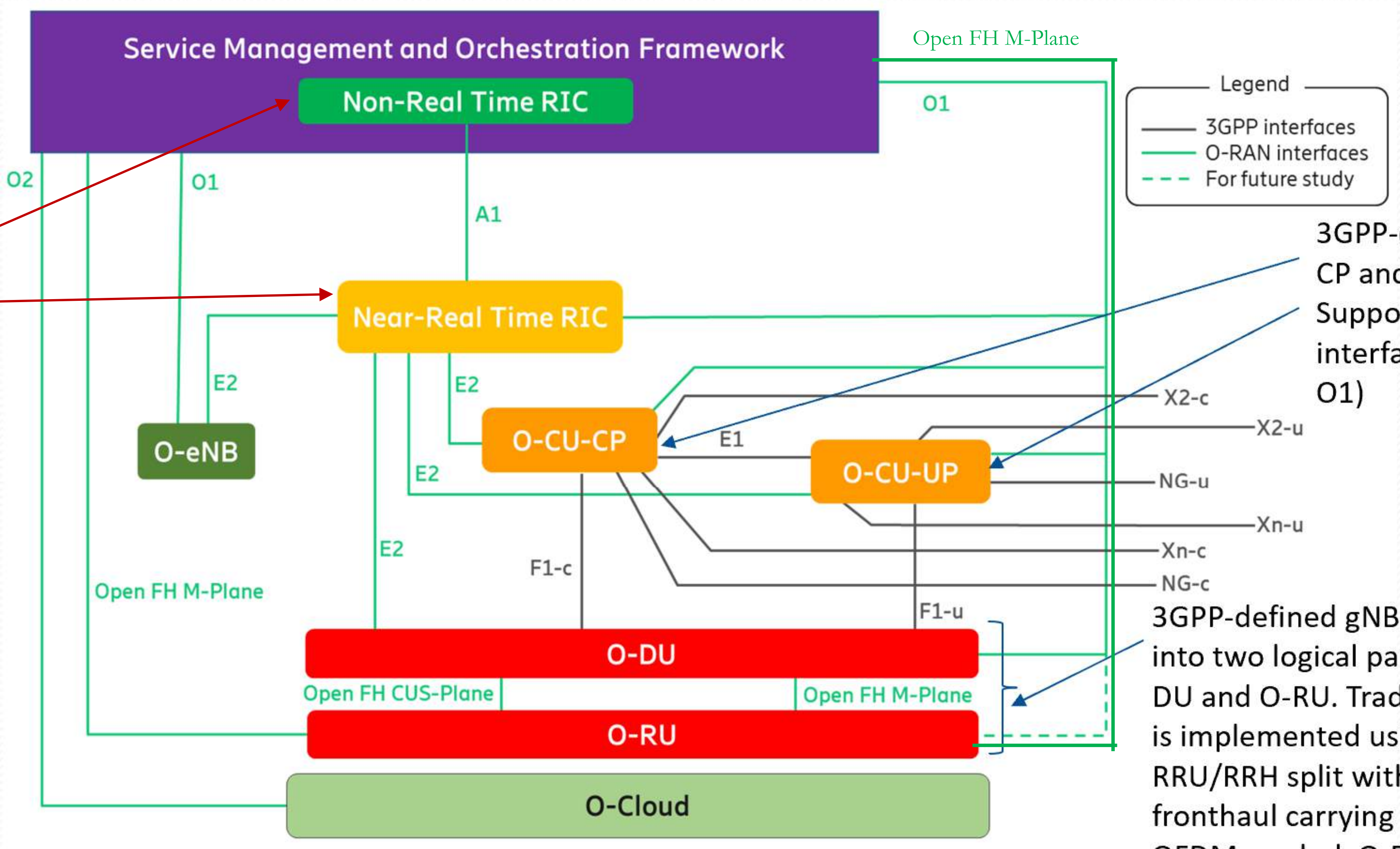
O-RAN Architecture by O-RAN Alliance

O-RAN: Open Radio Access Network
RIC: RAN Intelligent Controller
O-DU: O-RAN Distributed Unit
O-CU: O-RAN Central Unit
CP: Control Plane
UP: User Plane

Intelligence

Openness:
All interfaces "fully" defined
(reality: Will take time!)



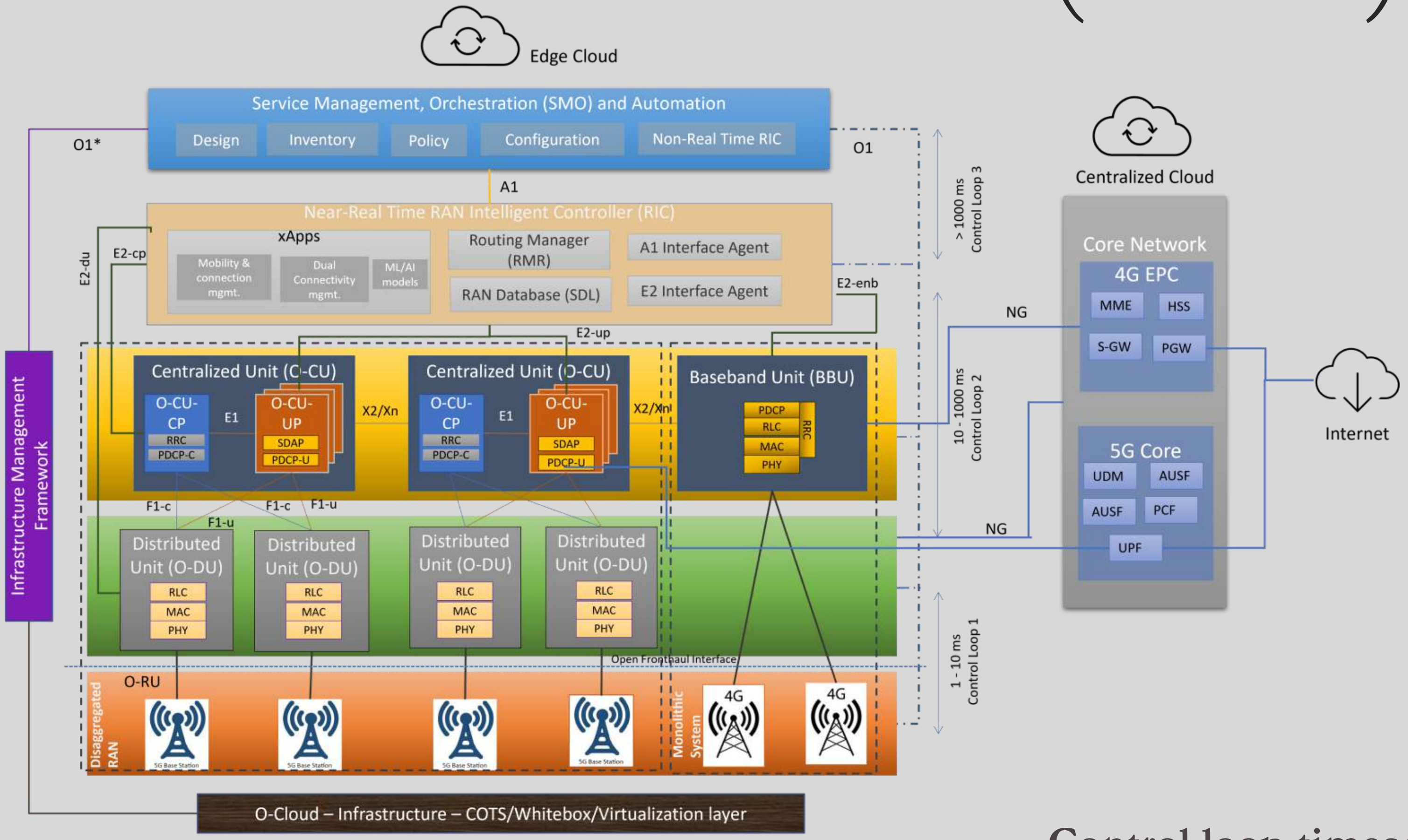
3GPP-defined gNB-CU-CP and gNB-CU-UP + Support for O-RAN interfaces (e.g., E2 and O1)

3GPP-defined gNB-DU is divided into two logical parts by O-RAN: O-DU and O-RU. Traditionally, gNB-DU is implemented using BBU-RRU/RRH split with CPRI/eCPRI on fronthaul carrying I/Q samples of an OFDM symbol. O-RAN uses a different approach, so-called 7.2x split, with IFFT in O-RU.

Acknowledgment. This diagram has been borrowed from the reference mentioned here.

[Reference: O-RAN Alliance, O-RAN Architecture Description 5.0 - July 2021]

O-RAN Architecture (cont'd)



- **Non-real time RIC** - enables non-real-time control and optimization of RAN elements and resources, AI/ML workflow over A1 interface.
- **Near real time RIC** - control and optimization of O-RAN elements and resources via fine-grained data collection and actions over E2 interface.
- **O-DU** - hosts RLC/MAC/High-PHY layers
- **O-CU-CP** - hosts the RRC and the control plane part of the PDCP protocol.
- **O-CU-UP** - hosts the user plane part of the PDCP protocol and the SDAP protocol.
- **xApp** - Independent software plug-in to the Near-RT RIC platform to provide functional extensibility to the RAN by third parties

Control loop timescales :

- Real time : < 1ms
- Near-real time : 10ms – 1000ms
- Non-real time : > 1s

Work Groups in the O-RAN Alliance

Group	Key Area of Focus
WG1: Use Cases and Overall Architecture Work Group	Define overall O-RAN architecture and use cases
WG2: The Non-Real-Time RAN Intelligent Controller and A1 Interface Work Group	Support Non-RT intelligent radio resource management, higher layer procedure optimization, policy optimization in RAN, and transfer of AI/ML models to Near-RT RIC
WG3: The Near-Real-Time RIC and E2 Interface Work Group	Define the Near-RT RIC architecture and support for data collection and actions over E2 interface
WG4: The Open Fronthaul Interfaces Work Group	Define open fronthaul interfaces to enable multi-vendor DU-RRU interoperability
WG5: The Open F1/W1/E1/X2/Xn Interface Work Group	Define 3GPP-compliant multi-vendor profile specifications for F1/W1/E1/X2/Xn interfaces and propose 3GPP specification enhancements (if any)
WG6: The Cloudification and Orchestration Work Group	Enable decoupling of RAN software from the underlying hardware platforms to produce technology and reference designs that leverage commodity hardware platforms
WG7: The White-box Hardware Work Group	Specify and release a complete reference design to foster a decoupled software and hardware platform
WG8: Stack Reference Design Work Group	Develop the software architecture, design, and release plan for the O-CU and O-DU based on O-RAN and 3GPP specifications for the NR protocol stack
WG9: Open X-haul Transport Work Group	Specify transport equipment, physical media and control/management protocols associated with the transport network
WG10: OAM Work Group	Specify the OAM requirements, OAM architecture and the O1 interface
WG11: Security Work Group	Address security aspects of the O-RAN ecosystem

SDFG: Standard Development Focus Group	Determine the standardization strategies and interface with other Standard Development Organizations (SDOs)
OSFG: Open Source Focus Group	Successfully launched the O-RAN Software Community (OSC) [The group is now dormant because the open source software development activities are being carried out by the OSC]
TIFG: Testing and Integration Focus Group	Defines the overall approach for testing and integration including coordination of test specifications across various WGs
nGRG: next Generation Research Group	Carry out research of open and intelligent RAN principles in 6G and future network standards

Focus and research Groups in the O-RAN Alliance

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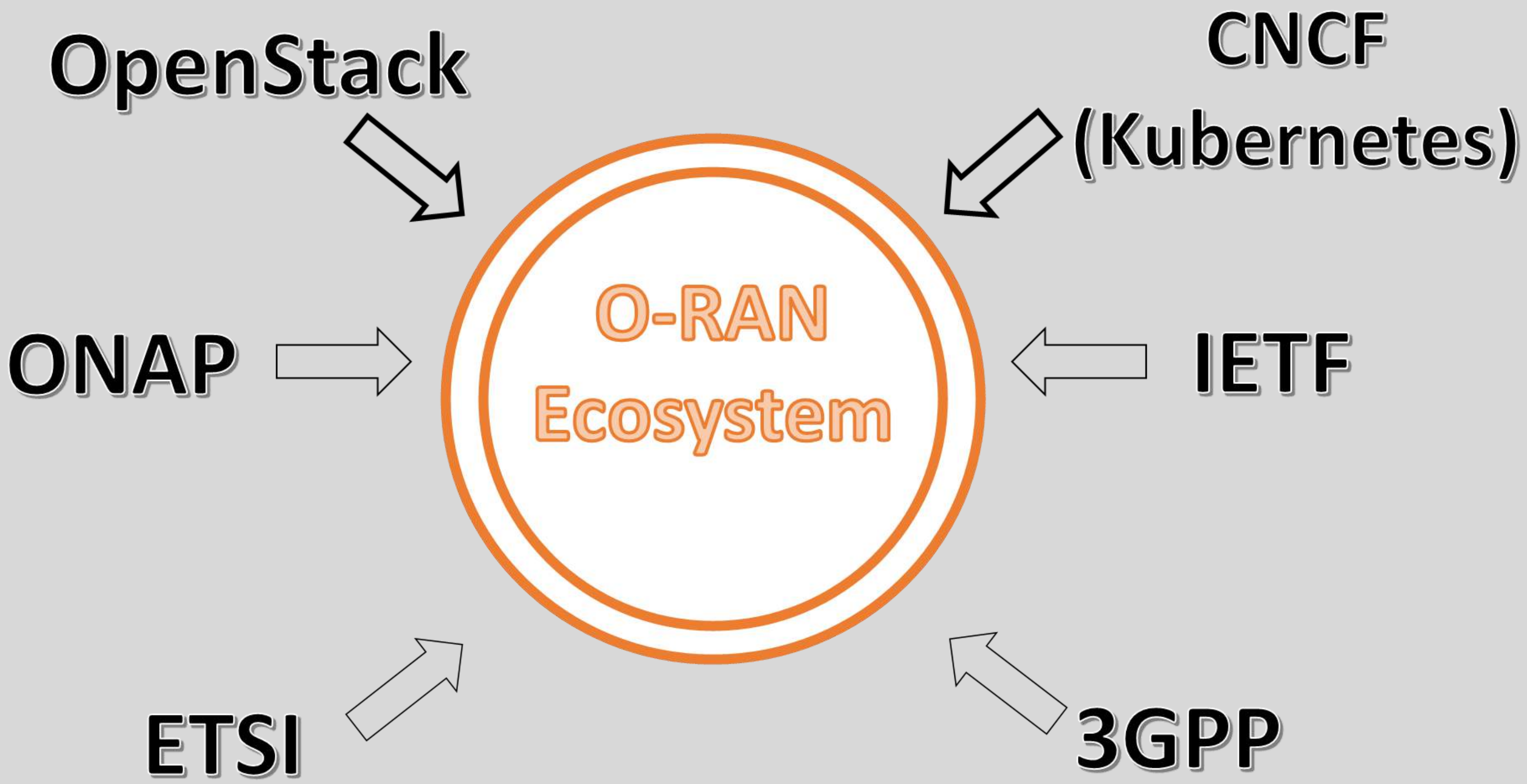
O-RAN: External Ecosystem

- ✓ O-RAN cannot be developed and implemented in isolation; assistance from several organizations is needed!



3GPP: Third Generation Partnership Project (Ex: specifications of gNB-CU and gNB-DU and the associated interfaces)
CNCF: Cloud Native Computing Foundation (Kubernetes or K8s specifications to implement RICs as "containerized applications")
IETF: Internet Engineering Task Force (Ex: IP security)
ETSI: European Telecommunication Standards Institute (Ex: Network Functions Virtualization architecture)
ONAP: Open Network Automation Protocol (Ex: Manage functions and/or components of a virtualized network through automation and orchestration)
OpenStack: Open-source cloud software that can be used to manage O-Cloud compute, storage, and networking resources

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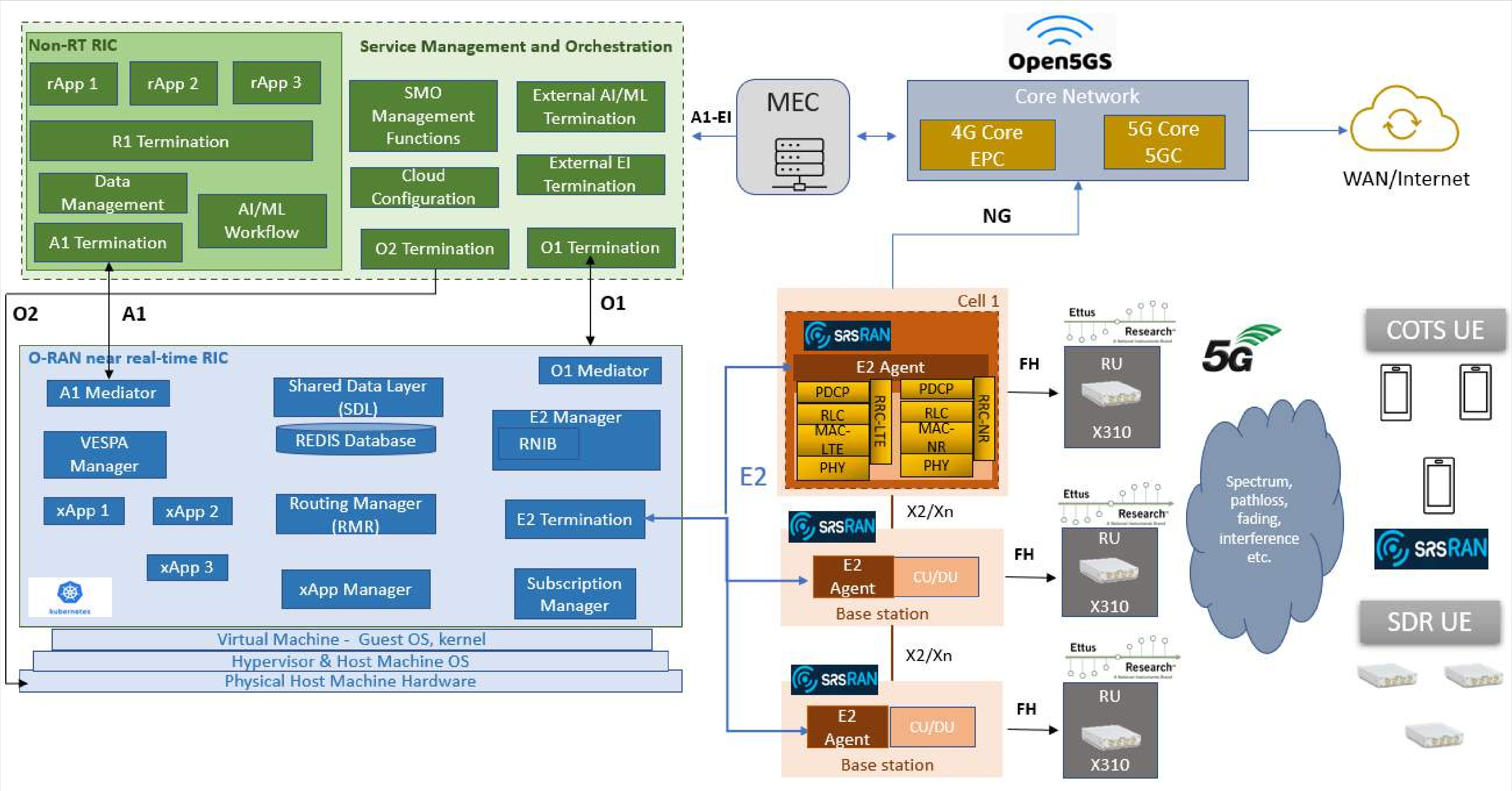
VIRGINIA TECH O-RAN TESTBEDS

Open AI Cellular (OAIC) Platform

- **<u>OAIC Mission:</u>** Provide an open platform for prototyping and testing artificial intelligence-based radio access network controllers for 6G research

O-RAN Architecture + 5G NR Protocol + Software Radios

- Open-Source
- Open-Source RAN
- Real-time execution and experiments with Software Defined Radios (SDRs)/USRPs
- Modes: with and wthout SDRs



High Level Overview of Different Components in the O-RAN Ecosystem

OAIC Framework: Example Options

O-RAN component	**OAIC implementation**
O-CU, O-DU, O-RU	srsRAN-5G with USRPs, new/enhanced interfaces
5G Core	Open5GS
E2 interface	O-RAN Software Community (OSC)
RAN Intelligent Controller (RIC)	OSC + real time RIC extension
xApps	Existing and new

OAIC Community Software

- Pulled from one repository (plus submodules)
- Easily installed (e.g., a Virtual Machine)
- Includes a suite of test programs that the user can run to ensure it built and installed properly
- Does not require custom hardware to test on (e.g., run through ZMQ and not rely on USRPs or other SDR hardware)
- Runs in a GitHub action workflow to verify full installation and execution (e.g. stand up a 5G network, start a basic xApp, and run traffic)

x

OAIC Features- I

Near-Real Time RIC

- Based on O-RAN Software Community's Near-RT RIC
- Compliant with E-release – Updated to H release soon.

Cellular Stack

- Based on Software Radio Systems RAN (srsRAN) – OAI to be released soon
- Support for 5G NSA/SA
- Integrated E2 Agent that interacts with Near-RT RIC (OSC based & FlexRIC based)
- Ettus USRPs (software radio hardware)
- ZeroMQ/RF Simulator (no radio hardware)
- Access to CORNET Testbed (planned)

USRP: Universal Software Radio Peripheral

OAIC Features- II

xAppps

- KPI Monitoring xApp
- Scheduling xApp
- Slicing xApp
- Test/Hello World xApp.
- MCS control xApp (To be released soon)
- UE Connection Control xApp (To be released soon)

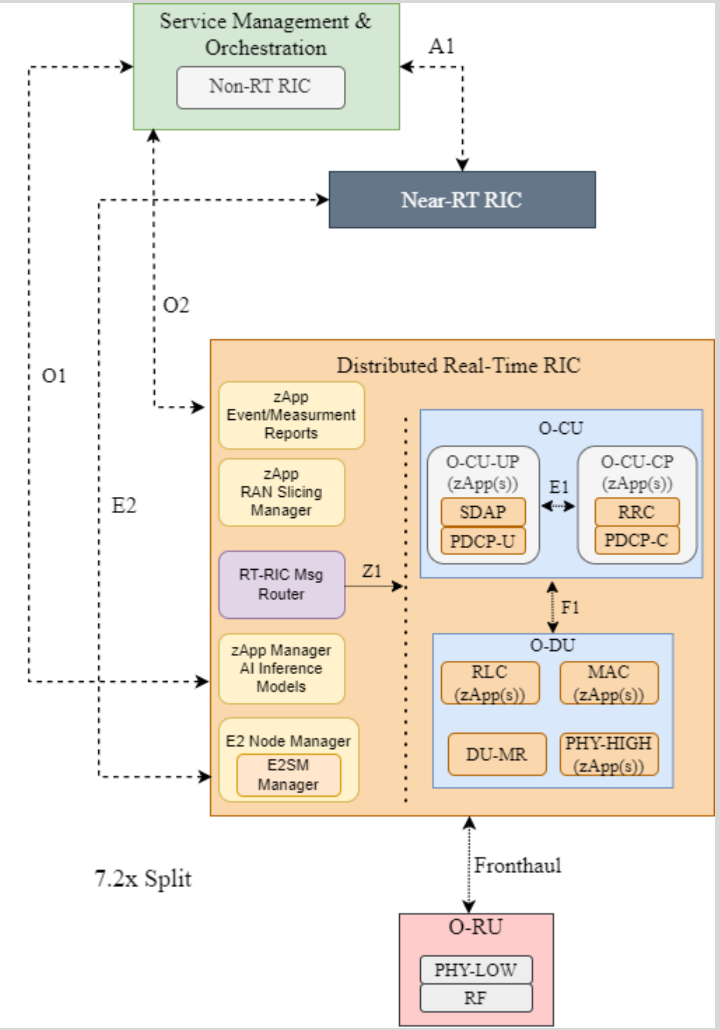
- Many others to be developed

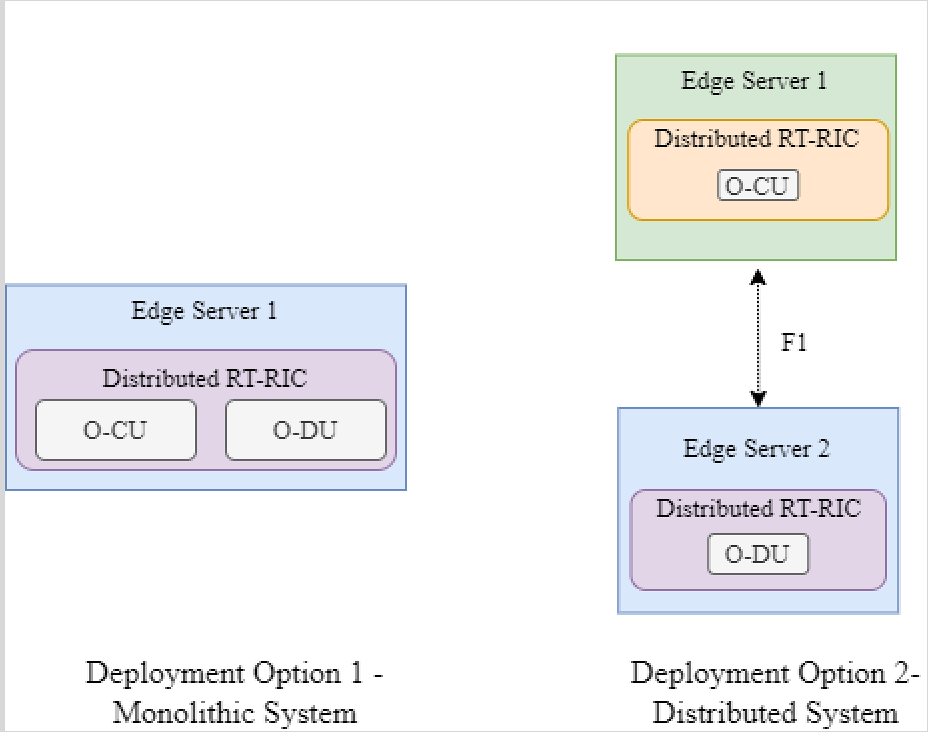
Beyond xApps

- Real-time control loop for AI-enhanced PHY control

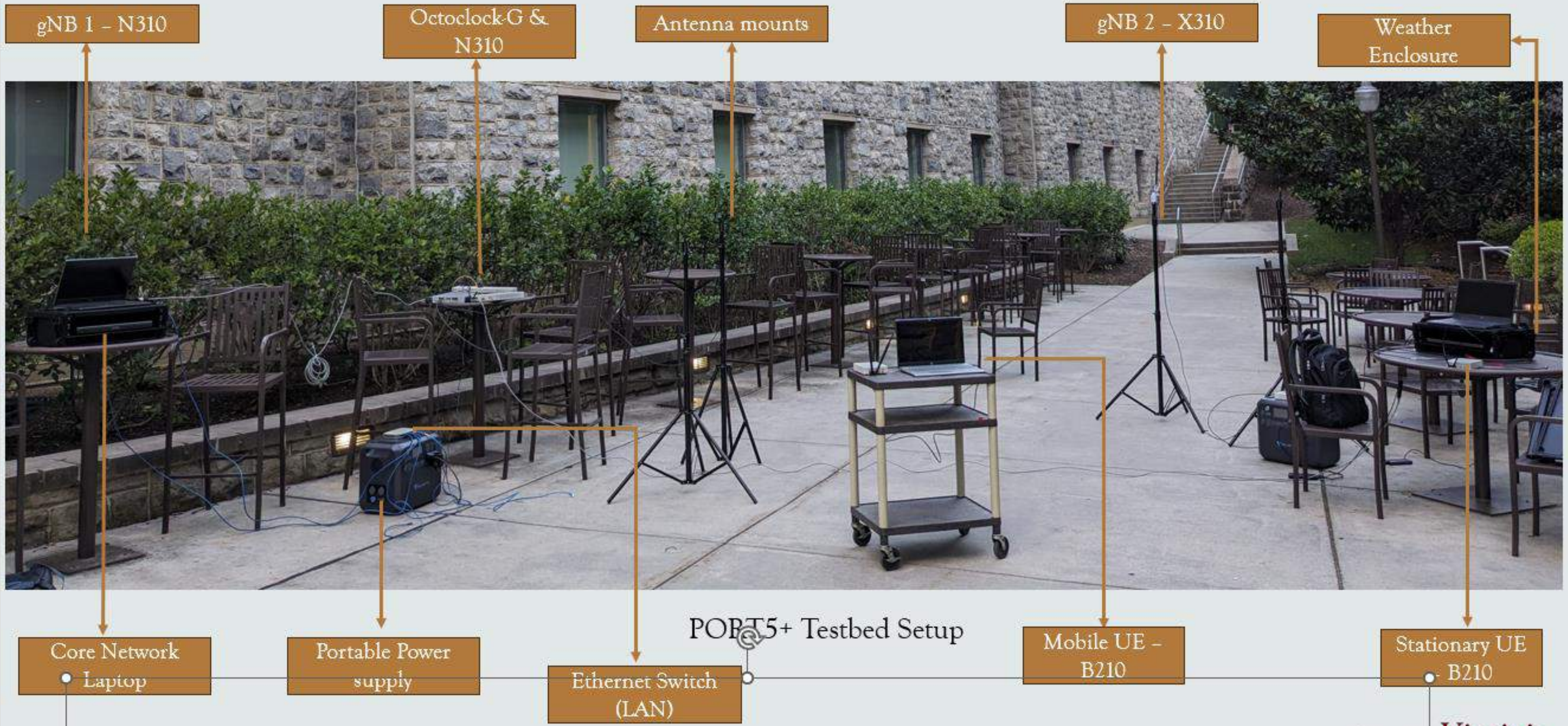
USRP: Universal Software Radio Peripheral

Real Time RIC Architecture





PORT5+ Testbed: Portable O-RAN Enabled 5G Testbed



PORT5+ Testbed Setup

- gNBs are connected to the Core Network through a switch.
- The Core Network uses a Wi-Fi Backhaul (*eduroam* campus wide WIFI) to provide internet connectivity to UEs.

Wireless @ Virginia Tech

Single gNB – Multiple UE setup

Objective: The UEs must be able to access internet utilizing the 5G link.

- Both the gNB and UE are USRP based and interface with the OAI gNB/UE stack, respectively.

Observations:

- gNB detection range : 12 meters radius approx.
- DL/UL Throughput for different types of traffic.
  - UDP based traffic (iperf): Avg. 60/12 Mbps (DL/UL). Peak DL throughput observed : 77 Mbps
  - TCP based traffic (speedtest.net): Avg. 30/8 Mbps.
  - Latency – UDP Traffic : 12 ms, TCP traffic: 30 ms.
- The UE throughput reduces when the gNB is serving the requests of multiple UEs.
  - 2 UE configuration : DL/UL throughput (UDP traffic) – UE 1: 30/6 Mbps, UE 2: 18/4 Mbps.
  - Can be remedied by having increasing the number of CPU threads used by gNB.

Q&A

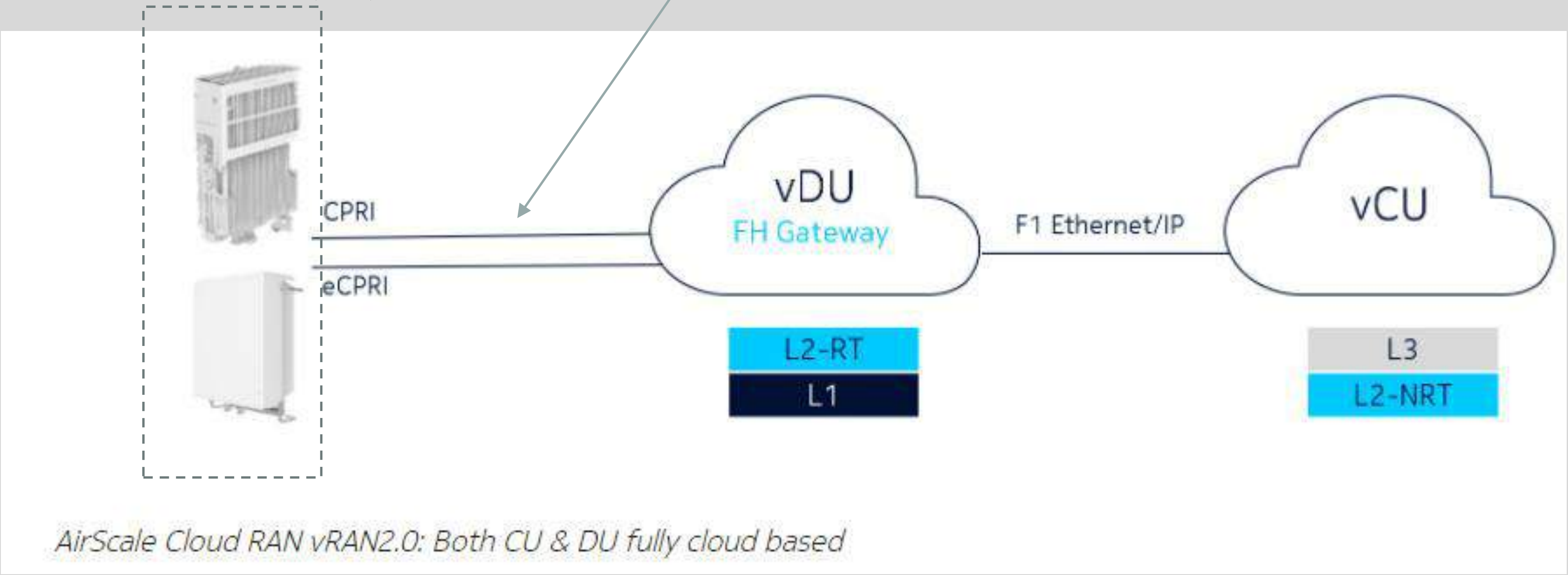
THANK YOU

Disaggregated gNB: Nokia

The disaggregated architecture can be virtualized.

Radio Unit (RU)

Likely to be traditional baseband signal I/Q samples



Reference:
https://www.nokia.com/blog/cloud-ran-goes-prime-time-as-nokia-and-att-prove-fully-virtualized-capabilities/

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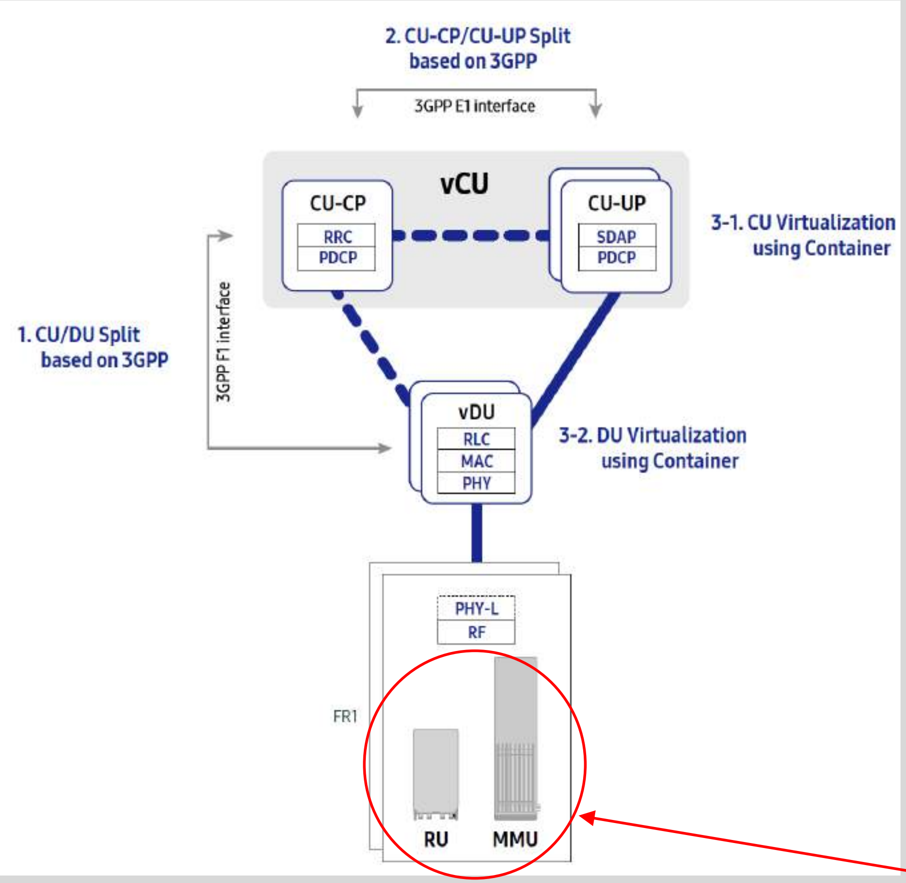

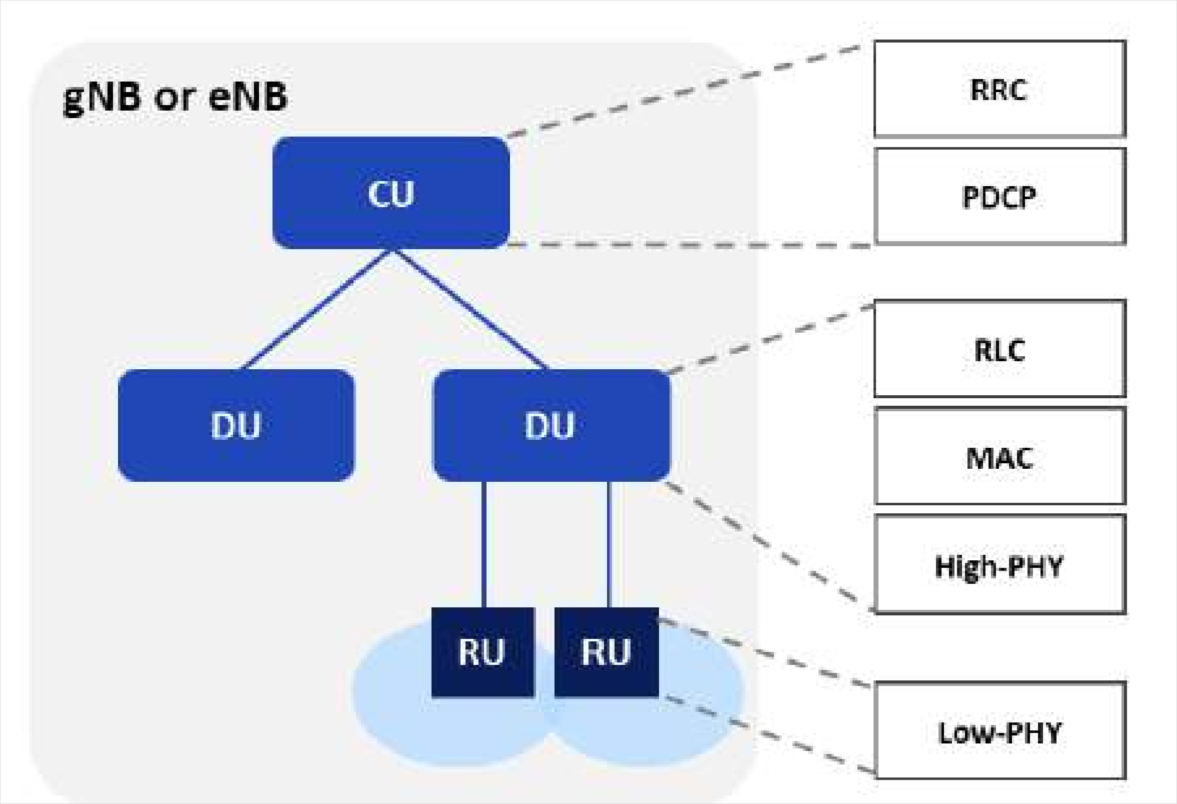

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