

Open RAN과 AI

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용어

- ❖ **vRAN(Virtualized RAN, 가상화 기지국) / Cloud RAN**
 - 범용 HW를 활용한 RAN 장비 구성(HW, SW 분리)
- ❖ **O-RAN : O-RAN Alliance 또는 O-RAN 규격을 의미**
 - RAN가상화 & 클라우드화, 개방형 인터페이스, 지능형 RAN 컨트롤러를 주요기술로 함
- ❖ **OpenRAN : TIP에서 추진중인 프로젝트명 (범용HW사용, 제조사 종속성 탈피)**
- ❖ **Open RAN : HW와 SW를 분리하고 개방형 인터페이스를 활용**
 - Open RAN과 Open vRAN을 구분하여 표현하는 경우도 있고, 이 경우 Open RAN은 개방형 인터페이스 적용, Open vRAN은 vRAN과 개방형 인터페이스를 모두 적용한 것을 의미함

WHAT IS OPEN RAN

❖ Open RAN (Radio Access Network)

- 오픈랜이란 무선 통신 장비의 하드웨어와 소프트웨어를 분리해, 서로 다른 제조사의 장비끼리도 연동이 가능하도록 하는 기술이다. 소프트웨어를 내려받는 방식으로 개별 기지국별로 원하는 기능을 탑재해 선별적으로 실행할 수 있어, 통신사들이 특정 공급 업체에 의존하지 않아도 된다.
- 세 가지 핵심 키워드: '개방화' '가상화' '지능화'

- Open RAN 기술은 O-RAN alliance에서 제시한 O-RAN architecture를 따르는 radio access network (RAN)을 의미
- 오픈랜은 현재 상용화된 5G를 넘어 네트워크의 복잡도가 더욱 증가하는 6G 네트워크의 요구사항을 만족하기 위한 필수적인 기술

< 무선접속망(RAN) 환경 변화 >



ORIA

❖ 오픈랜 인더스트리 얼라이언스(ORIA)

- 한·미 정상회담 후속 조치로 오픈랜 협력을 강화
- 이동통신 3사와 삼성전자, LG전자 등 30여개 기업·기관이 참여
- 정부는 오픈랜 장비 국제인증체계(K-OTIC)를 구축하는 등 '



ORIA가 구축할 K-OTIC이 담당하는 주요 역할 및 기능 [자료=과기정통부]

Source: <https://www.industrynews.co.kr/news/articleView.html?idxno=50687>

O-RAN 사용 이유는?

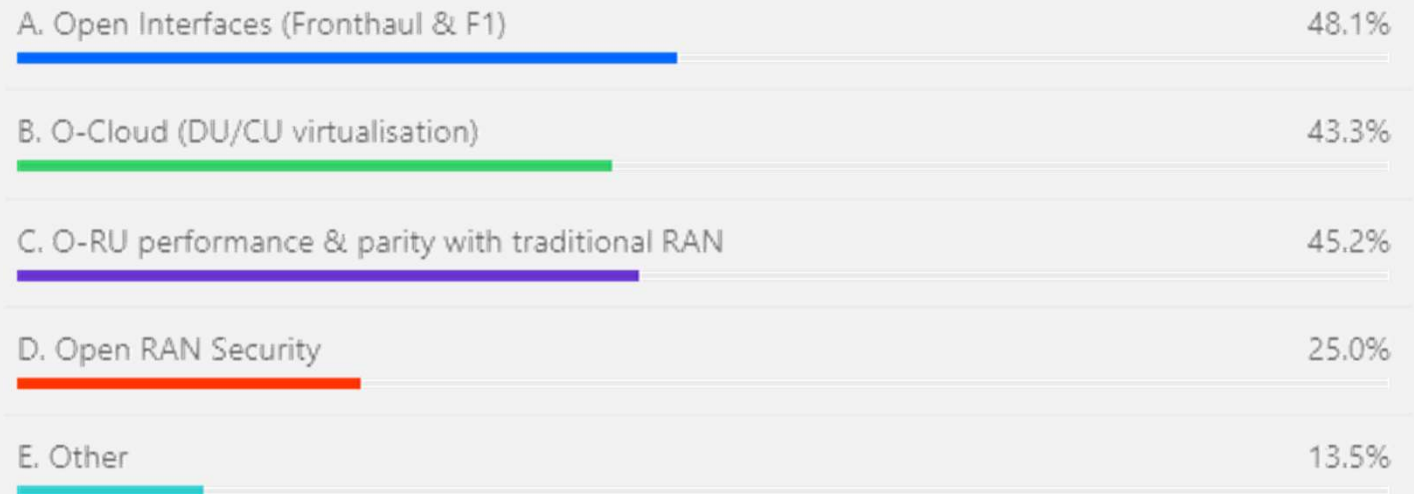
❖ 온라인 세미나 참여자의 O-RAN 사용 이유는?

- 오픈 인터페이스
- O-Cloud (DU/CU 가상화)
- O-RU
- 보안
- 기타

Slides

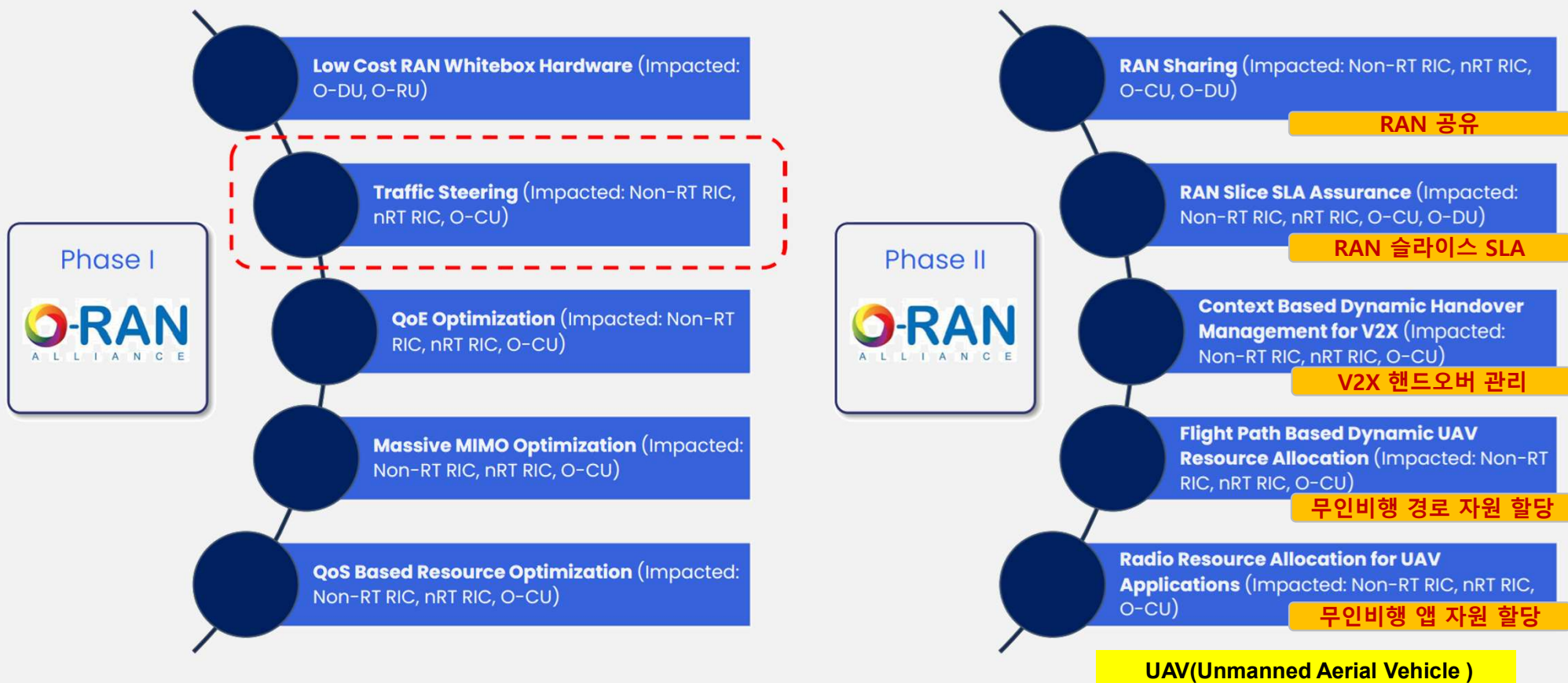


Which part of Open RAN is your company most interested in? (select multiple if applicable)



O-RAN USE CASES

❖ O-RAN Use Cases

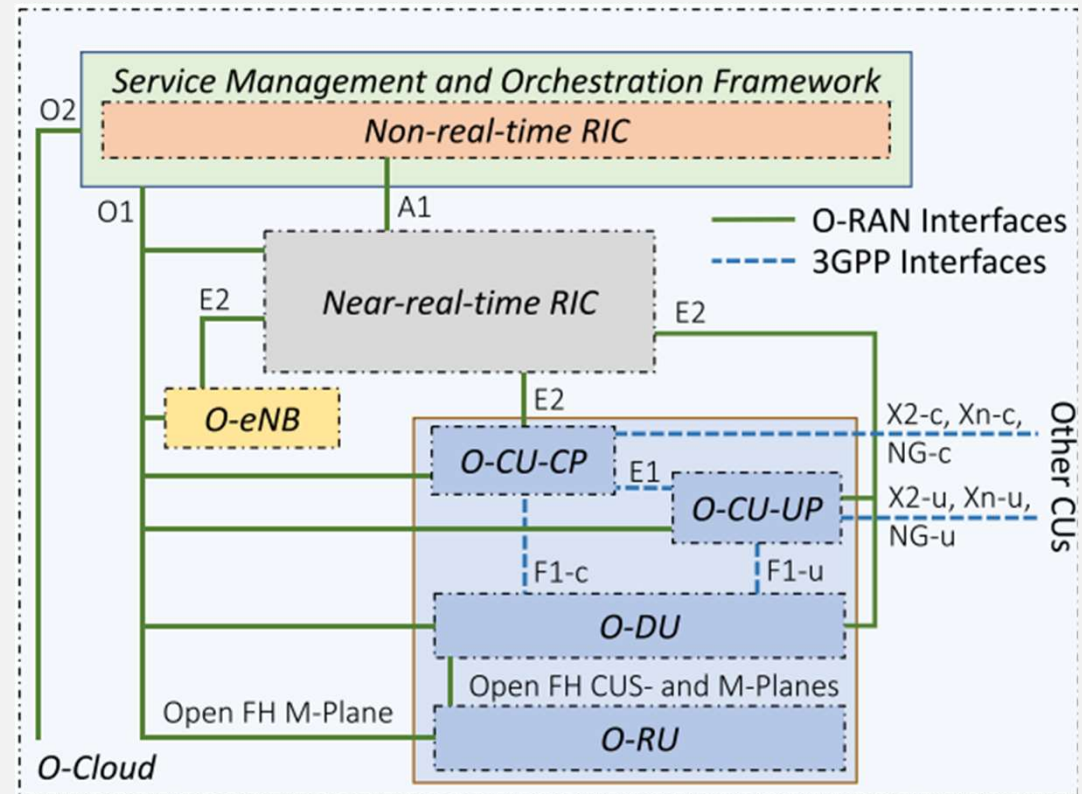


Source: www.rimedolabs.com, <https://wiki.o-ran-sc.org/display/REL/I+Release>,

O-RAN ARCHITECTURE

❖ **O-RAN architecture, with components and interfaces from O-RAN and 3GPP. O-RAN interfaces are drawn as solid lines, 3GPP ones as dashed lines.**

- **Non-Real-time RIC (NONRTRIC)**
- **Near-Real-time RIC X-APPs (RICAPP)**
- **Near-Real-time RAN Intelligent Controller Platform (E2 Interface) (RICPLT)**
- **Operation and Maintenance (OAM)**
- **O-RAN Central Unit (OCU)**
- **O-DU High (ODUHIGH)**
- **O-DU Low (ODULOW)**
- **Simulators (SIM)**
- **Service Management and Orchestration Layer (SMO)**
- **Infrastructure (INF)**
- **Integration and Test (INT)**
- **AIML Framework (AIMLFW)**
- **Documentation (DOC)**

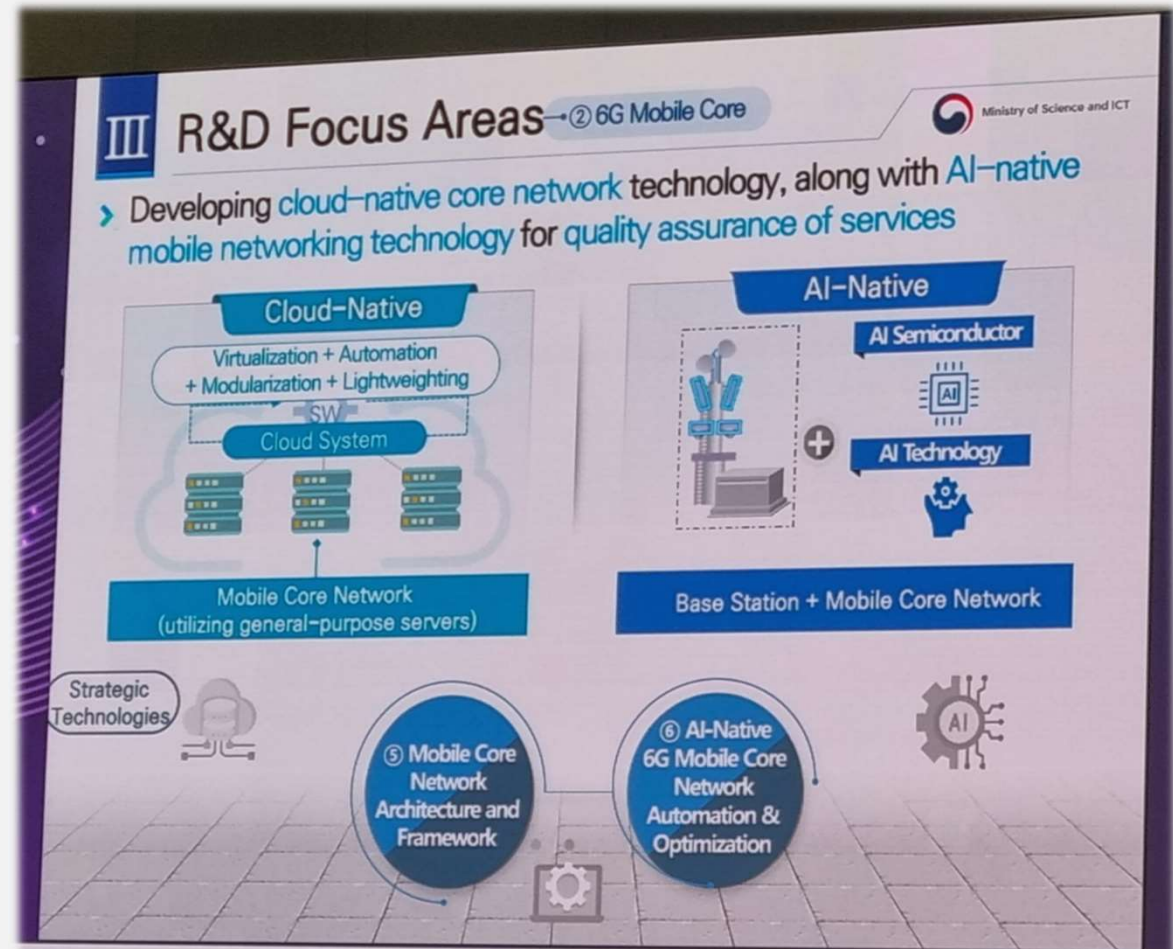


Source: Understanding O-RAN, Architecture, Interfaces, Algorithms, Security, and Research Challenges, IEEE

6G MOBILE CORE

❖ 6G Mobile Core (과학기술정보통신부)

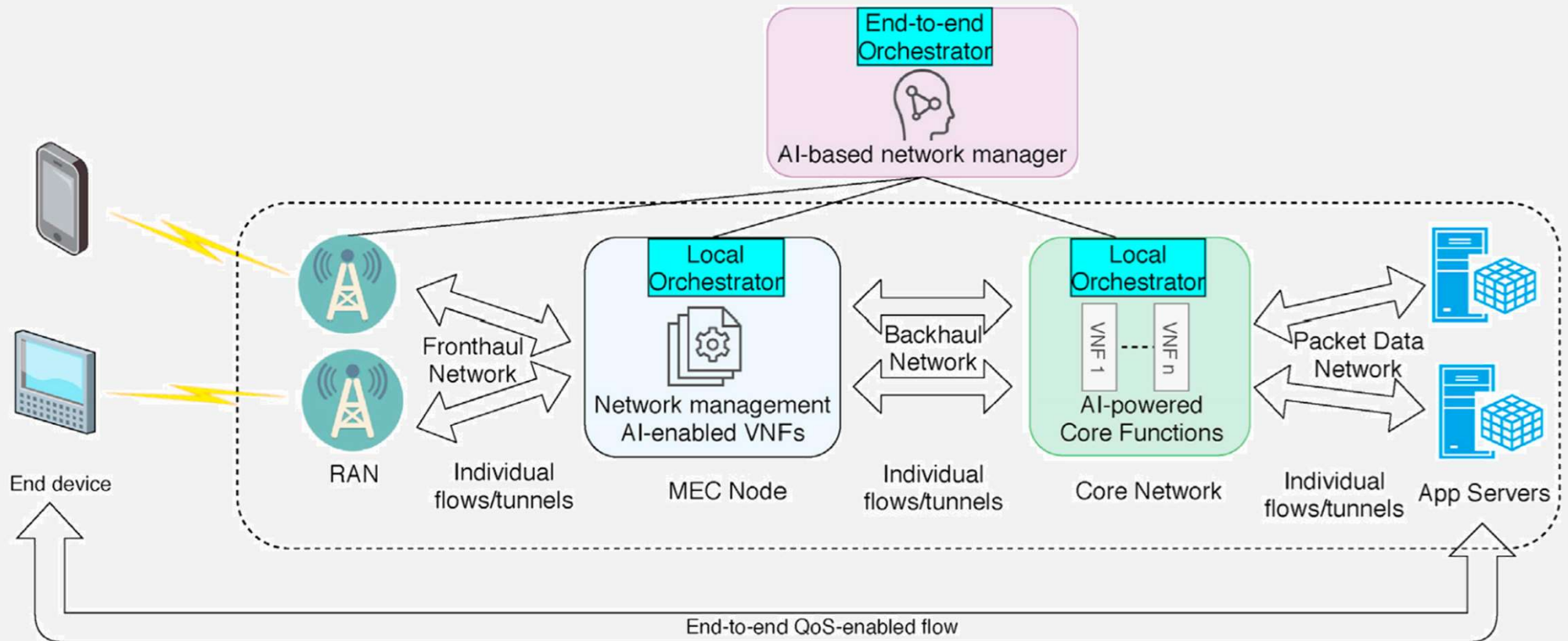
- Cloud-native Core Network
- AI-native mobile networking



Source: 과기정통부 @ Mobile Korea 2023

ZSM

❖ Overall Zero-touch Network and Service Management (ZSM) vision.

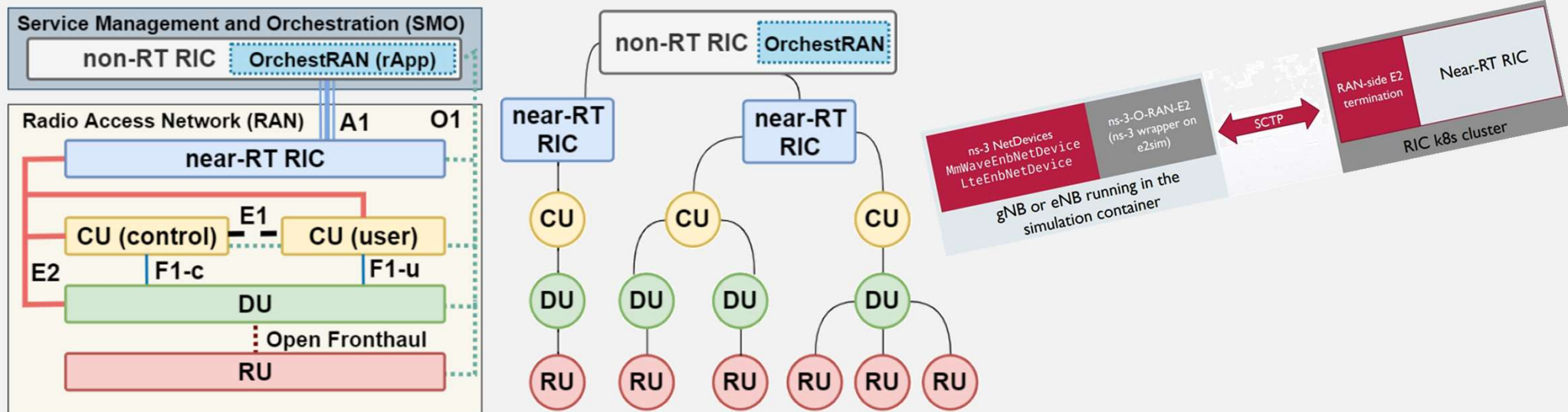


Source: Machine learning-based zero-touch network and service management, Jorge Gallego-Madrid, Ramon Sanchez-Iborra, Pedro M. Ruiz, Antonio F. Skarmeta

ORCHESTRATING IN THE OPEN RAN

❖ Orchestrating intelligence in the Open RAN

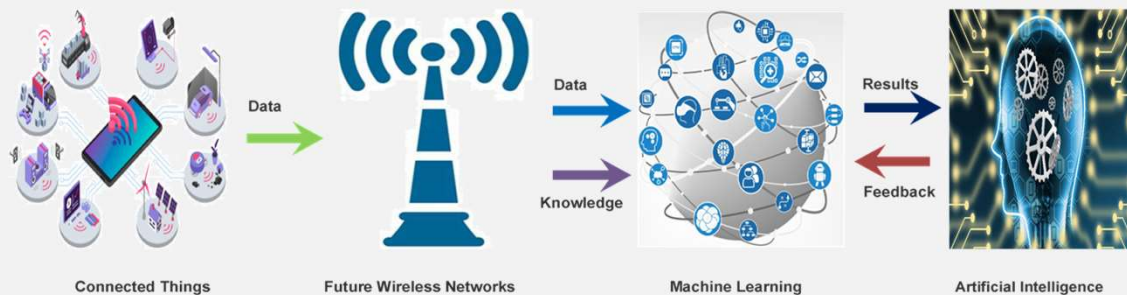
- Intent recognition
- Optimized intelligence placement
- Automated deployment/execution/management of intelligence



ML-BASED SOLUTION FOR 5G NETWORK

❖ ML-based solution for 5G network (예)

- 트래픽 예측
- 슬라이스 제어
- 보안
- 자원 할당
- 저지연
- DNN
- mmWave
- 기타



Source: <https://www.mdpi.com/1424-8220/22/1/26/htm>

Author References	적용 분야 Key Contribution	적용 방법 ML Applied	Network Participants Component		5G Network Application Parameter					
			RAN	Core	LB	SDN	RAN	RA	SEC	
Alave et al. [68]	Network traffic prediction	LSTM and DNN	✓	✓				트래픽 예측	✓	X
Bega et al. [15]	Network slice admission control algorithm	Machine Learning and Deep Learning	✓	X				슬라이스 제어	✓	X
Suomalainen et al. [69]	5G Security	Machine Learning	X	✓				보안	✓	✓
Bashir et al. [70]	Resource Allocation	Machine Learning	✓	✓				자원 할당	✓	X
Balevi et al. [71]	Low Latency communication	Unsupervised clustering	X	✓				저지연	✓	X
Tayyaba et al. [72]	Resource Management	LSTM, CNN, and DNN	✓	✓				DNN	✓	✓
Sim et al. [73]	5G mmWave Vehicular communication	FML (Fast machine Learning)	X	✓				mmWave	✓	X
Li et al. [74]	Intrusion Detection System	Machine Learning	X	✓				침입 탐지	✓	✓
Kafle et al. [75]	5G Network Slicing	Machine Learning	X	✓				슬라이스	✓	✓
Chen et al. [76]	Physical-Layer Channel Authentication	Machine Learning	X	✓				물리 계층	X	✓
Sevgican et al. [77]	Intelligent Network Data Analytics Function in 5G	Machine Learning	✓	X				데이터 분석	·	·

O-RAN LAB 구성(예)

❖ O-RAN Lab 구성 (예)

- 256 software-defined radios
- 25.6 GHz of emulated bandwidth, 52 TB/s RF data
- 21 racks of radios, 171 high-performance servers w/ CPUs, GPUs
- Massive computing capabilities (CPU, GPU, FPGA):
 - > 900 TB of storage
 - 320 FPGAs
 - 18 10G switches
 - 19 clock distribution systems
 - 52 TB/s of digital RF data

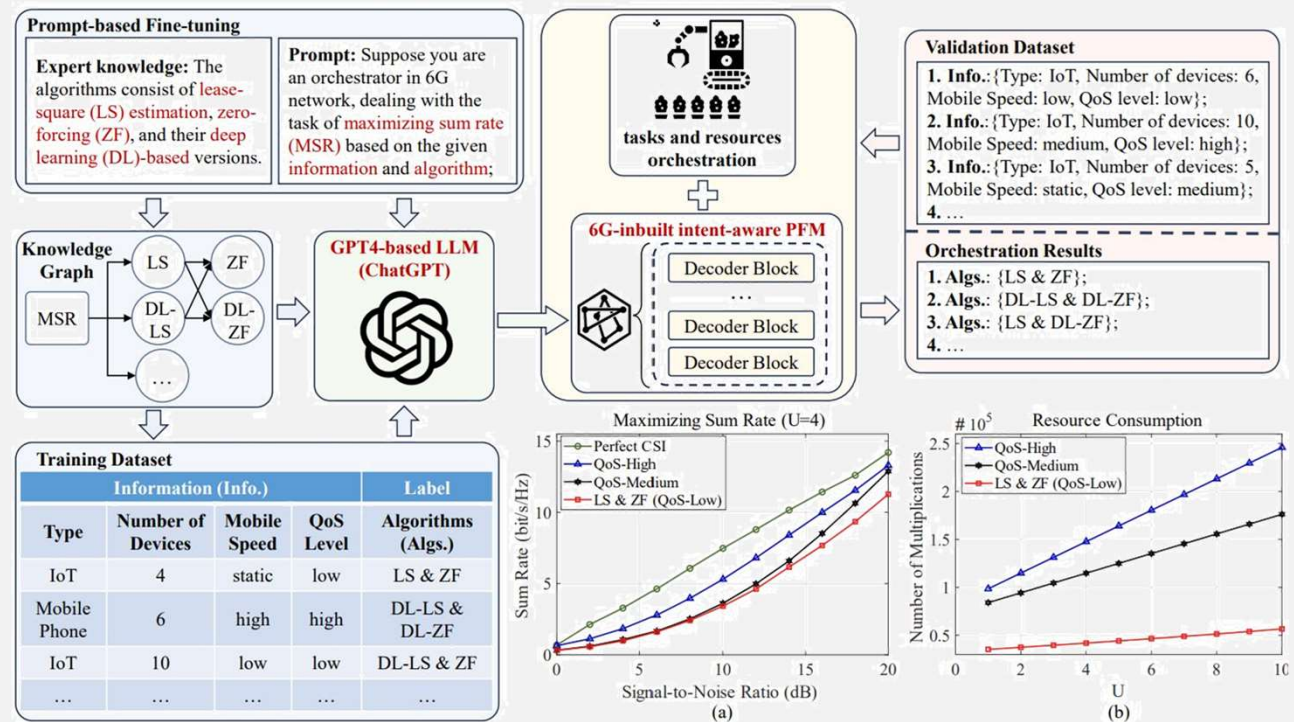


YANG models that help manage the radio units feature more than 6,000 parameters, with less than 3% of them mandatory, and network vendors also implement custom protocols.

Source: <https://openairinterface.org/wp-content/uploads/2022/11/8-Michele-Polese-Northeastern.pdf>

PRE-TRAINED FOUNDATION MODELS (PFM)

- ❖ The PFM customization and the case study of orchestration.
- ❖ Foundation Model Based Native AI Framework in 6G with Cloud-Edge-End Collaboration

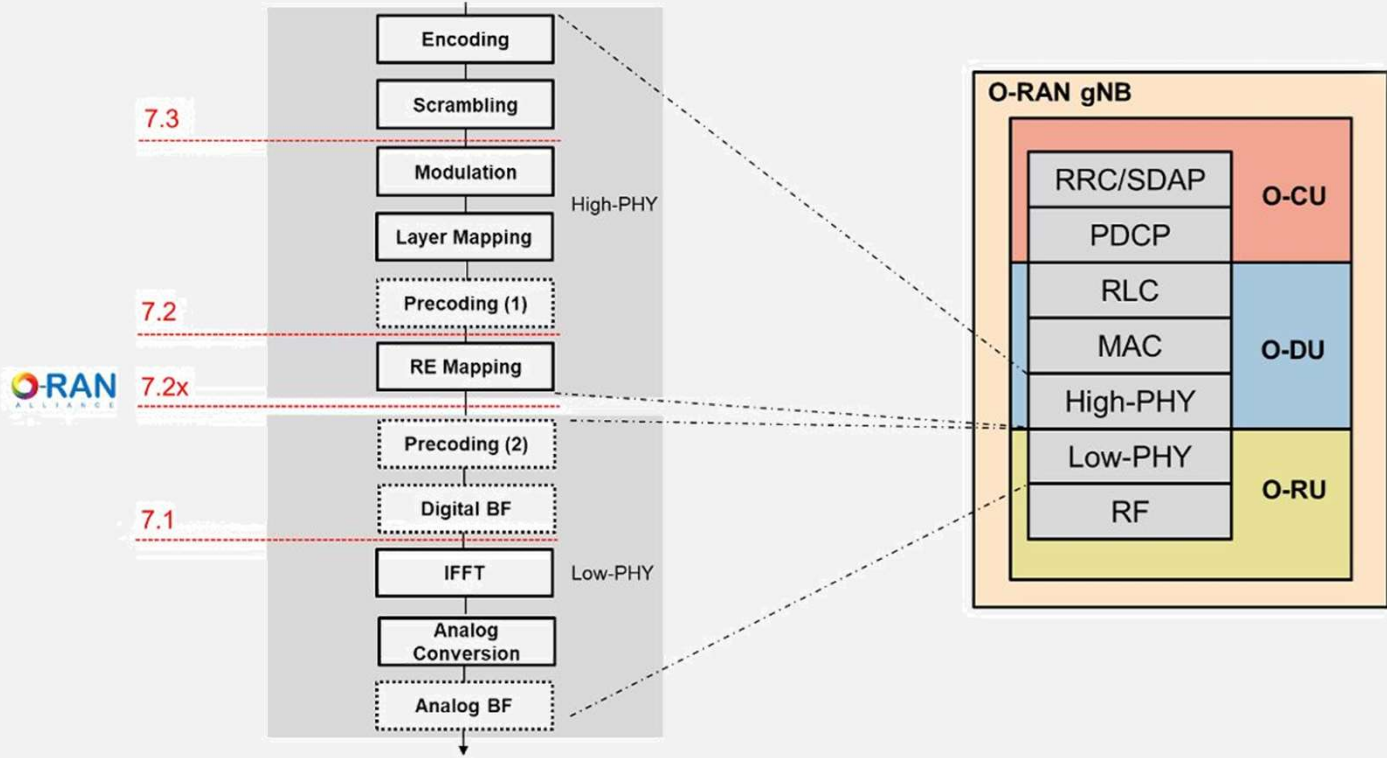


The PFM customization and the case study of orchestration.

O-RAN E2 INTERFACE

❖ O-RAN protocol hierarchy and 5G NR functional split

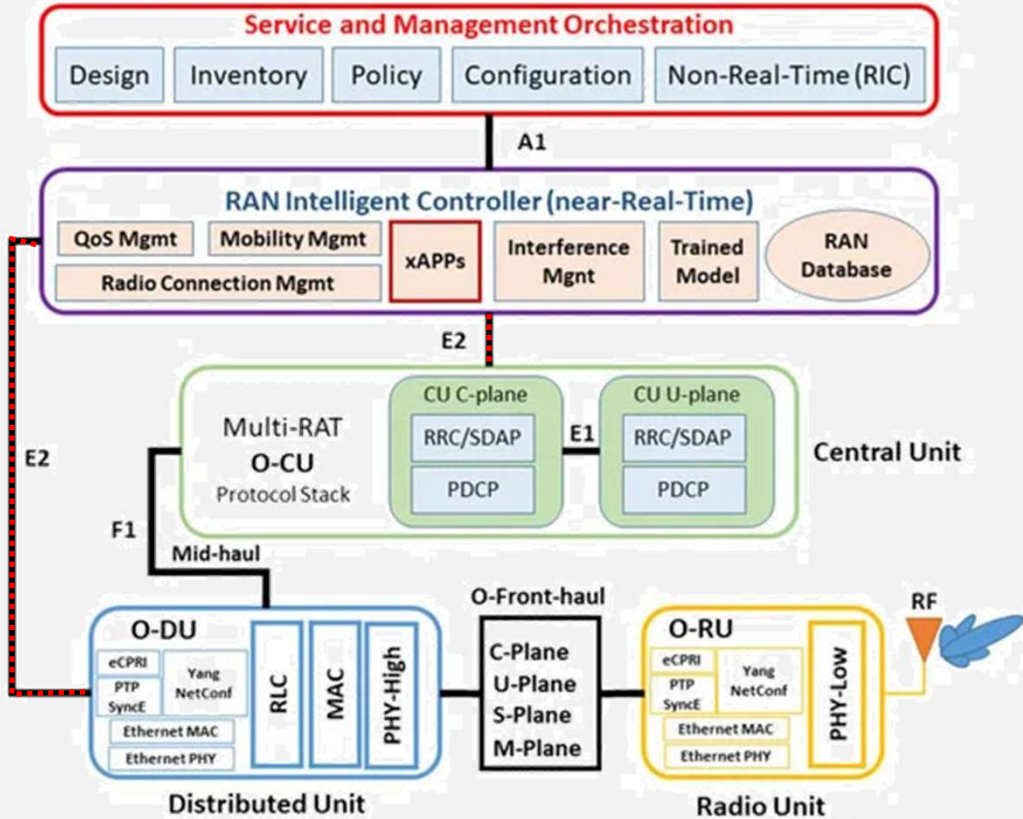
- **O-CU (O-RAN central unit)**, which manages the packet data convergence protocol (PDCP), service data adaptation protocol (SDAP), and radio resource control (RRC) protocol entities
- **O-DU (O-RAN distributed unit)**, which takes on tasks of the upper part of the physical layer (High-PHY), medium access control (MAC), and radio link control (RLC)
- **O-RU (O-RAN radio unit)**, which processes the RF and lower part of the physical layer (Low-PHY)



Source: <https://la.mathworks.com/discovery/o-ran.html>

O-RAN E2 INTERFACE

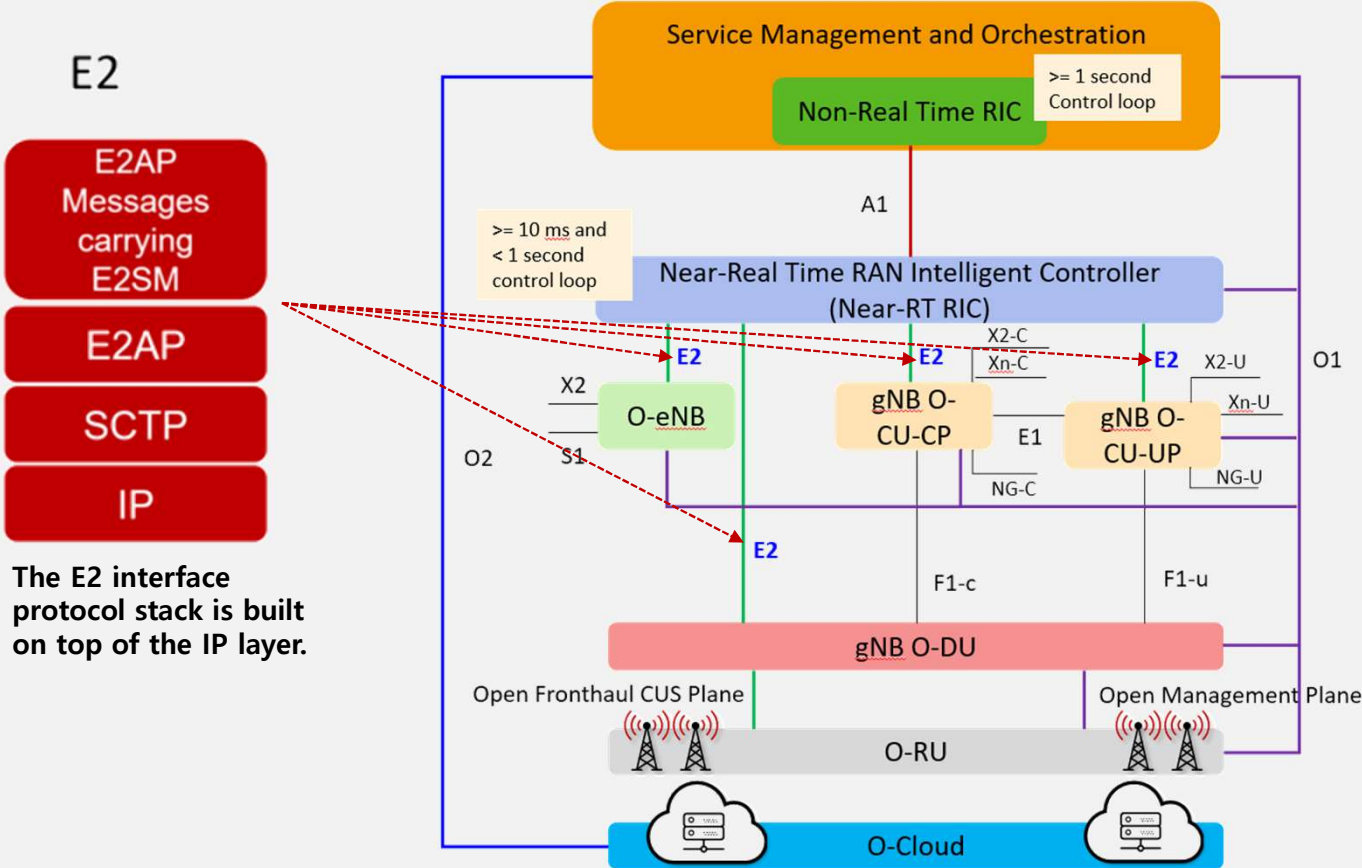
❖ O-RAN architecture (base station disaggregation and openness)



Source: <https://www.mdpi.com/2079-9292/10/17/2162>

O-RAN E2 INTERFACE

❖ How does 5G's O-RAN E2 interface work?



Source: <https://www.5gtechnologyworld.com/how-does-5gs-o-ran-e2-interface-work/?fbclid=IwAR3SeTWgvgq1LyJyflgWlpjx19pOp48Ezh0Hlw6YZ6F0q1x2Kmyvlj2jkfA>

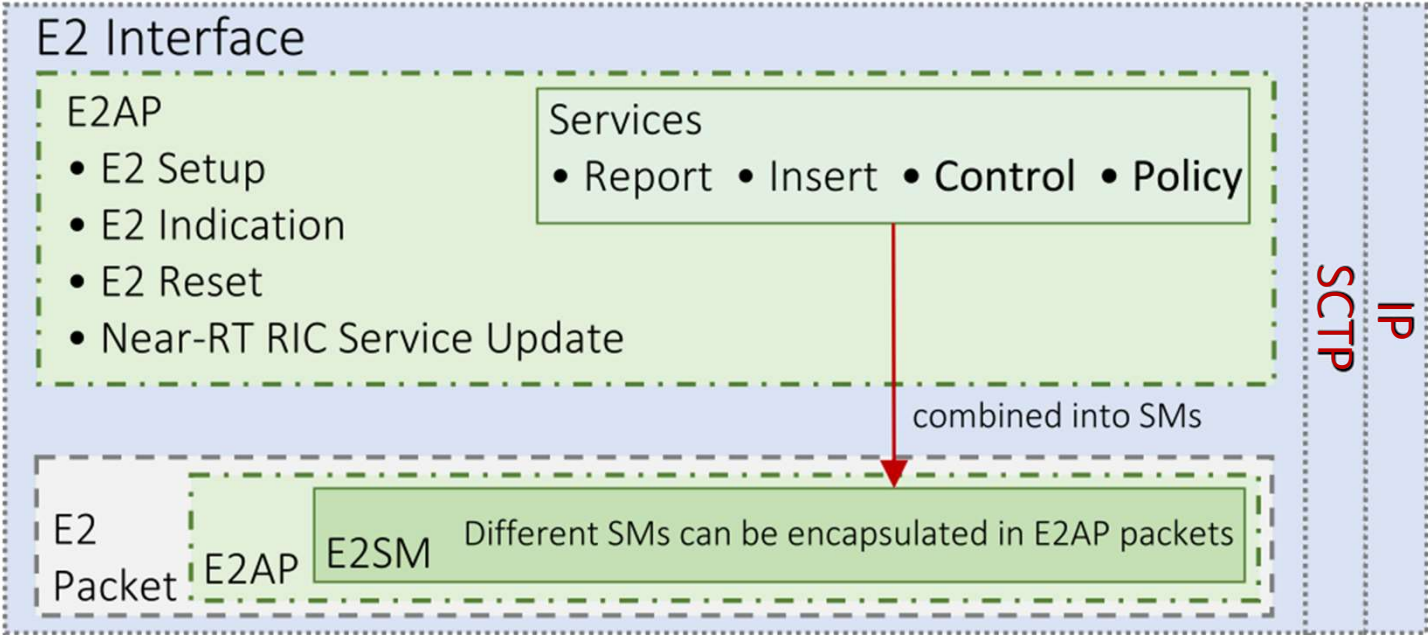
E2 INTERFACE

❖ O-RAN E2AP packet

- O-RAN E2AP packet (bottom left), which includes an E2SM payload (top left).
- The E2 payload is then encapsulated in SCTP and IP headers (right).
- The top part of the figure also summarizes the services provided by the E2 interface.

TCP/UDP와 함께 SCTP/IP
지원 네트워크 필요

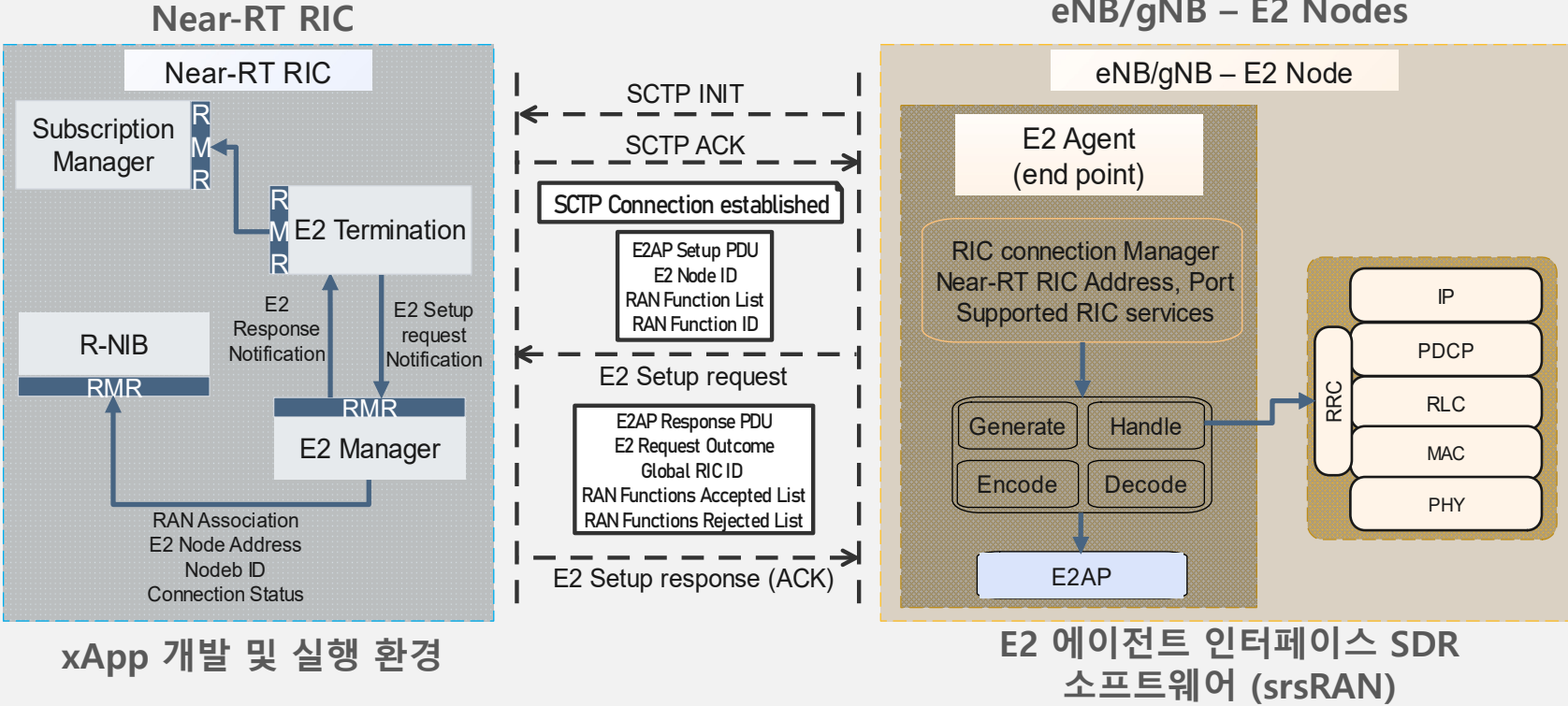
5G SCTP Load Balancer Tutorial
<https://github.com/open5gs/open5gs/discussions/2391>
 LoxiLB as an SCTP LoadBalancer
 with Open5GS



Source: Understanding O-RAN, Architecture, Interfaces, Algorithms, Security, and Research Challenges, IEEE

E2 SETUP

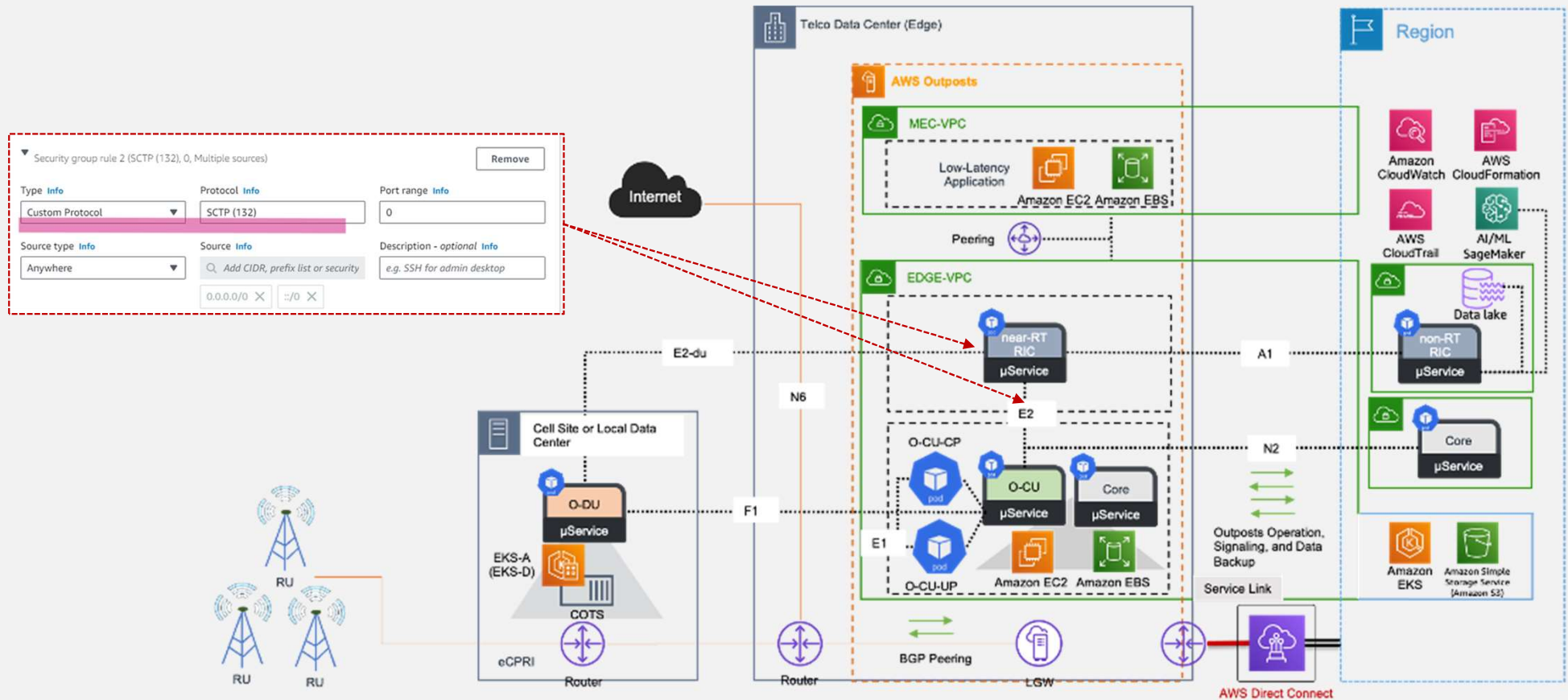
❖ E2 Setup: Connecting E2 Node (RAN) with near-RT RIC



Source: www.openaircellular.org

O-RAN ARCHITECTURE ON AWS

❖ O-RAN architecture on AWS



Source: <https://docs.aws.amazon.com/whitepapers/latest/open-radio-access-network-architecture-on-aws/o-ran-architecture-on-aws.html>

O-RAN ARCHITECTURE ON AWS

- ❖ Reference architecture for developing Non-RT RIC on AWS
- ❖ Tutorial for AWS (LoxiLB/Open5GS)

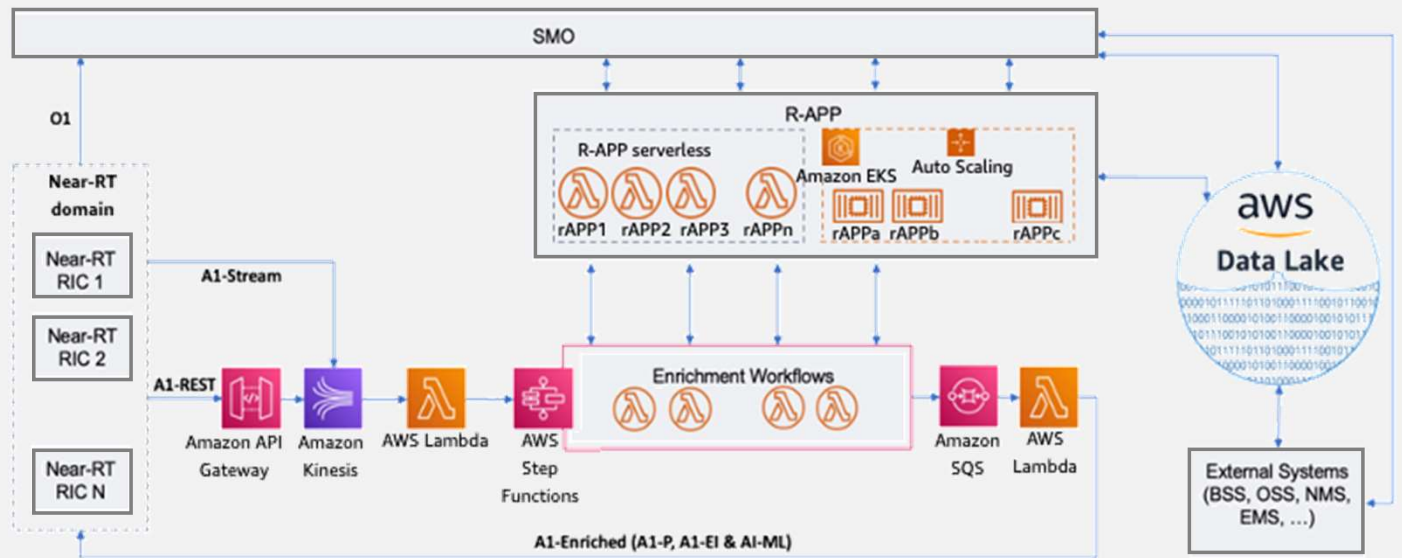

Using LoxiLB as an SCTP LoadBalancer with Open5GS

open5gs/open5gs

#2391 5G SCTP Load Balancer Tutorial

Show and tell 0 comments

infinitydon opened on June 21, 2023

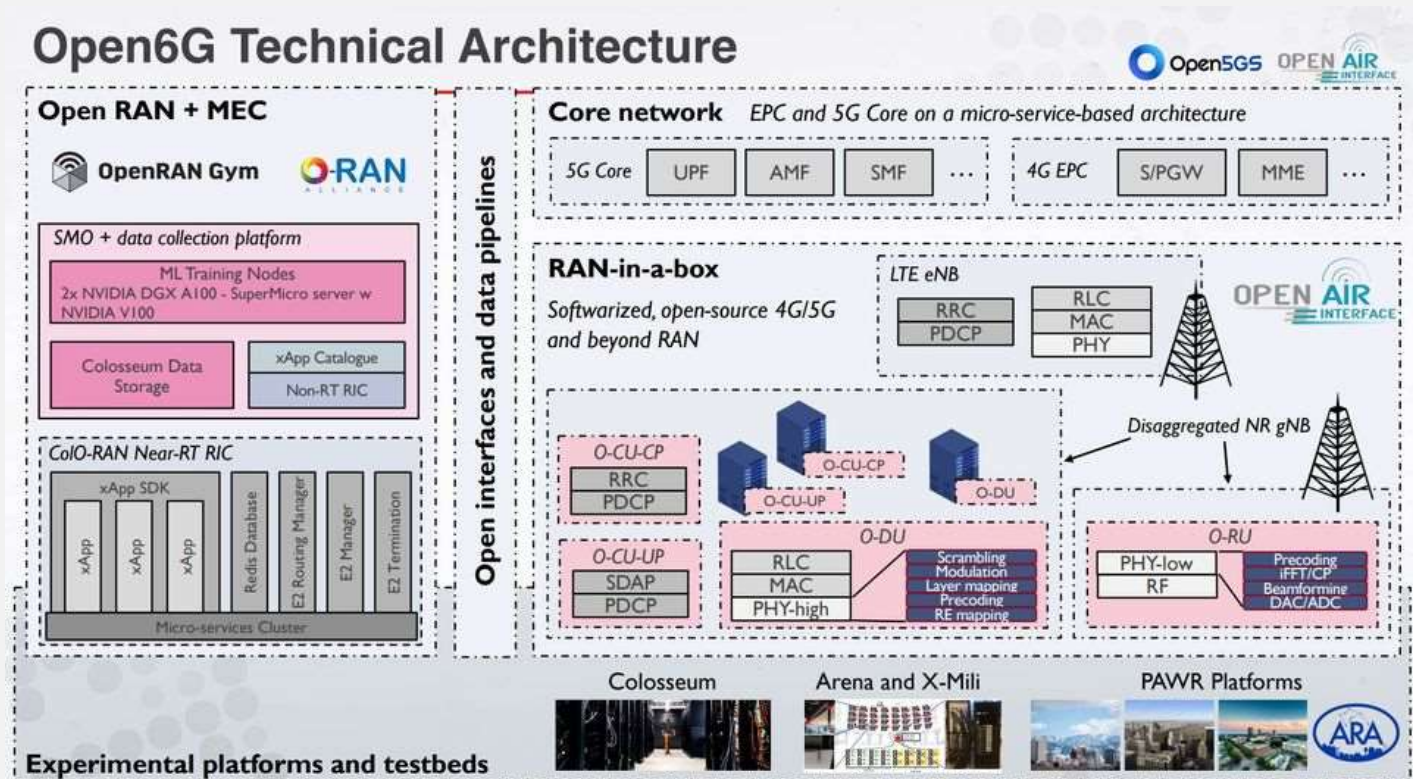


Source: <https://docs.aws.amazon.com/whitepapers/latest/open-radio-access-network-architecture-on-aws/o-ran-architecture-on-aws.html>, <https://github.com/open5gs/open5gs/discussions/2391?>

OPEN6G TECHNICAL ARCHITECTURE

❖ Open6G Technical Architecture

- O-RAN
- Open5GS
- Open AIR Interface
- K8s/LoxiLB for Cloud Native



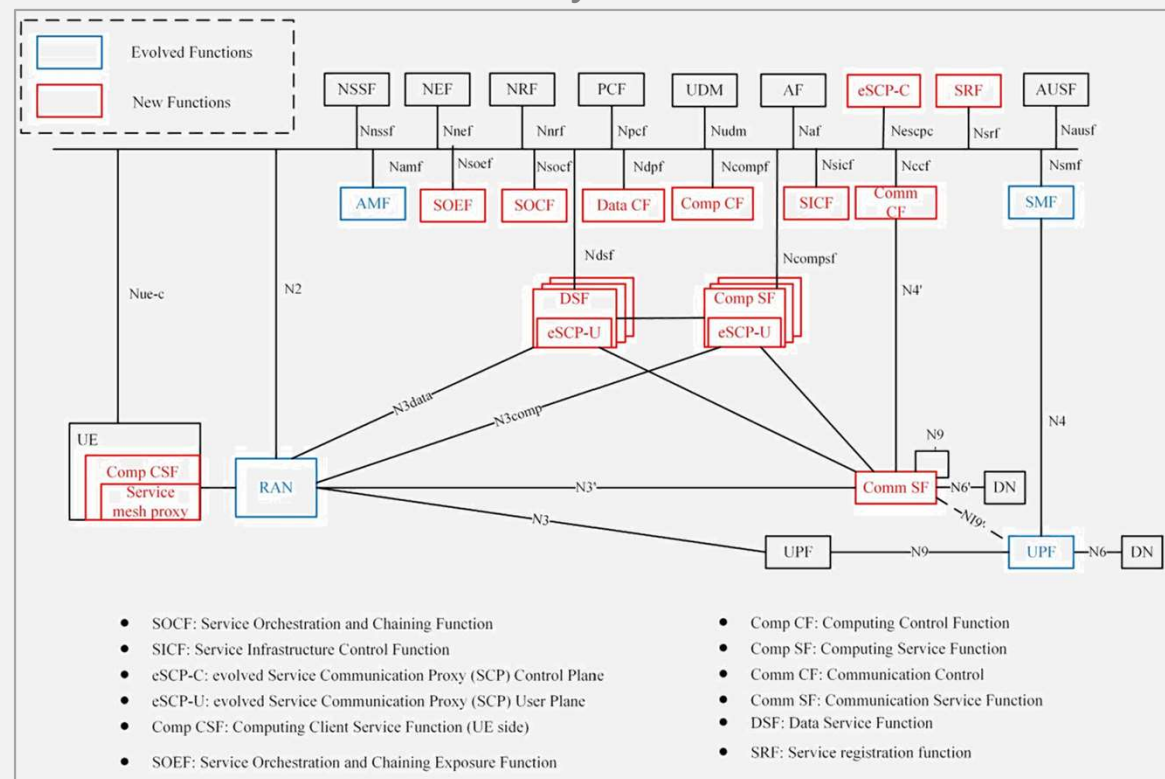
Source: <https://openairinterface.org/wp-content/uploads/2022/11/8-Michele-Polese-Northeastern.pdf>

6G CLOUD-NATIVE SYSTEM ARCHITECTURE

❖ 6G Cloud-Native System

- SICF (Service Infrastructure Control Function)
- DSP (Data Service Function)
- SCP (Service Communication Proxy)
- SRF (Service Registration Function)
- Comp SF (Computing Service Function)

6G Cloud-Native System Architecture

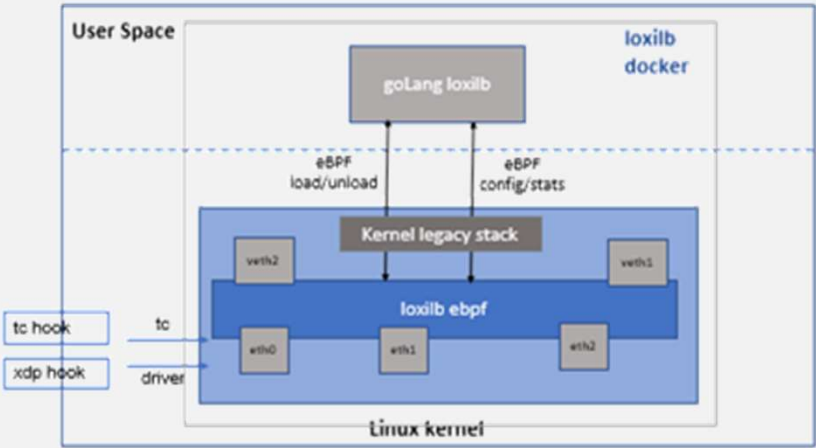


Source: <https://ieeexplore.ieee.org/document/9882121?denied=>

SCP FOR 5G/6G EDGE

❖ SCP(Service Communication Proxy) for Cloud Native 5G/6G Edge (예): eBPF based LoxiLB

- LB
- SCTP (Near-Real-Time RIC ↔ E2 Interfaces)
- goBGP
- SRv6
- GTP



The screenshot shows the 'eBPF Project Landscape' website. At the top, there is a banner for 'eBPF summit 2022 (28-29 September)' with a 'Register Now!' button. Below the banner is the eBPF logo and a navigation menu. The main content area features the heading 'Applications (Emerging)' and a sub-heading 'LoxiLB'. Underneath, it describes LoxiLB as an 'eBPF based cloud-native load-balancer for 5G Edge'. There are links for 'Website' and 'GitHub'. A brief description states: 'LoxiLB is an open-source cloud-native "external" service load-balancer for cloud-native 5G/edge workloads written from scratch using eBPF as its core-engine and based on Go Language. LoxiLB turns Kubernetes network load balancing for 5G/Edge services into high speed, flexible and programmable LB services.'

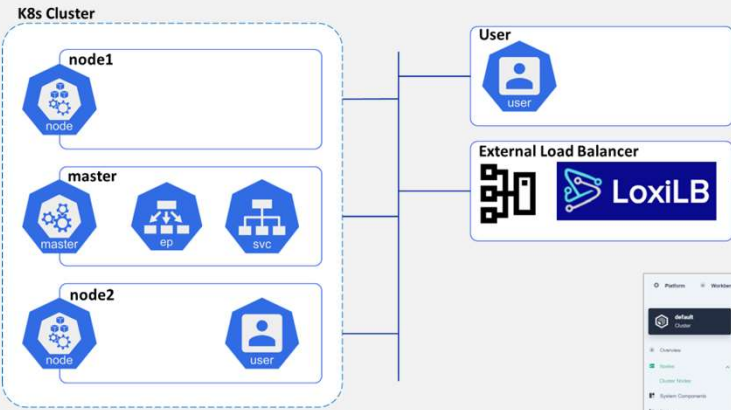
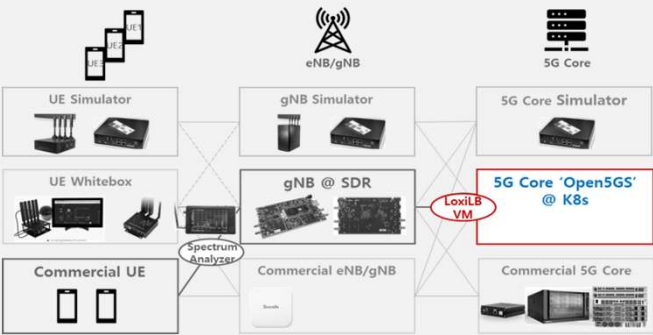
Source: <https://ebpf.io/projects/>

CLOUD NATIVE SDR TESTBED

❖ Cloud Native 5G Edge Testbed

- Cloud Native 5G (Open5GS)
- SCP (LoxiLB)
- Open SDR

- ❖ Cloud Native 5G Core: Open5GS (K8s 1 Master/2 Nodes)
- ❖ SCP(Service Infrastructure Proxy): LoxiLB (LB, Gateway and etc.)
- ❖ Tools: Console, Dashboard, Traffic Monitor



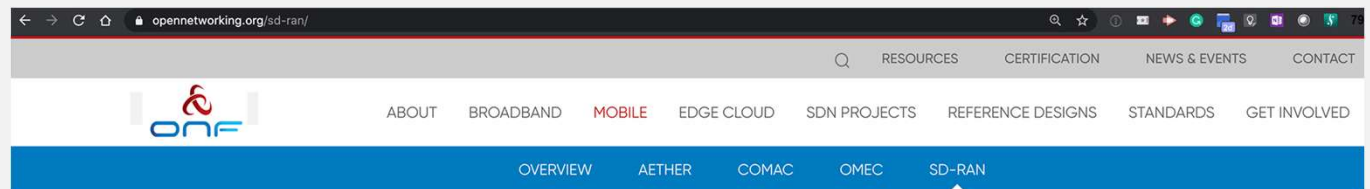
Three screenshots of monitoring and management tools. The top screenshot is the 'Traffic Monitor' dashboard, showing various graphs and tables for traffic analysis. The middle screenshot is the 'K8s Dashboard' (KUBESPHERE), displaying cluster nodes and their status. The bottom screenshot is the 'LoxiLB Console', showing a login form with fields for 'Username' and 'Password' and a 'Login' button.

Source: <https://www.youtube.com/watch?v=foSyhEpedWk>

ONOS RIC NEEDS LB FOR SCALABILITY

❖ μONOS RIC (Distributed)

- E2 Interfaces need LB for Scalability



μONOS RIC

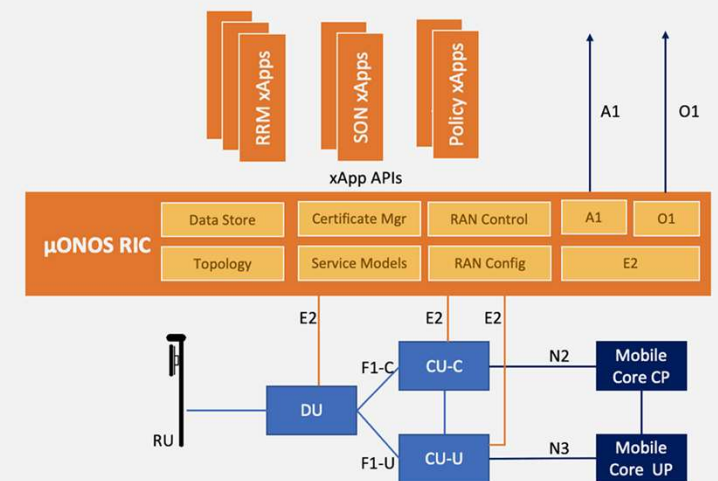
At the heart of ONF's SD-RAN architecture is the μONOS RIC, based on ONOS, the leading open source SDN control plane for operators.

ONOS RIC is a cloud-native, carrier-grade SDN controller that enables:

- Ease in scalability
- High performance
- High availability
- Support for multi-vendor equipment

The μONOS RIC uses a microservices architecture that includes the following elements:

- Certificate Manager
- Topology Manager
- Configuration Manager
- RAN Control Manager
- Distributed Store



Source: <https://convergedigest.com/onf-launches-5g-sd-ran-project/>

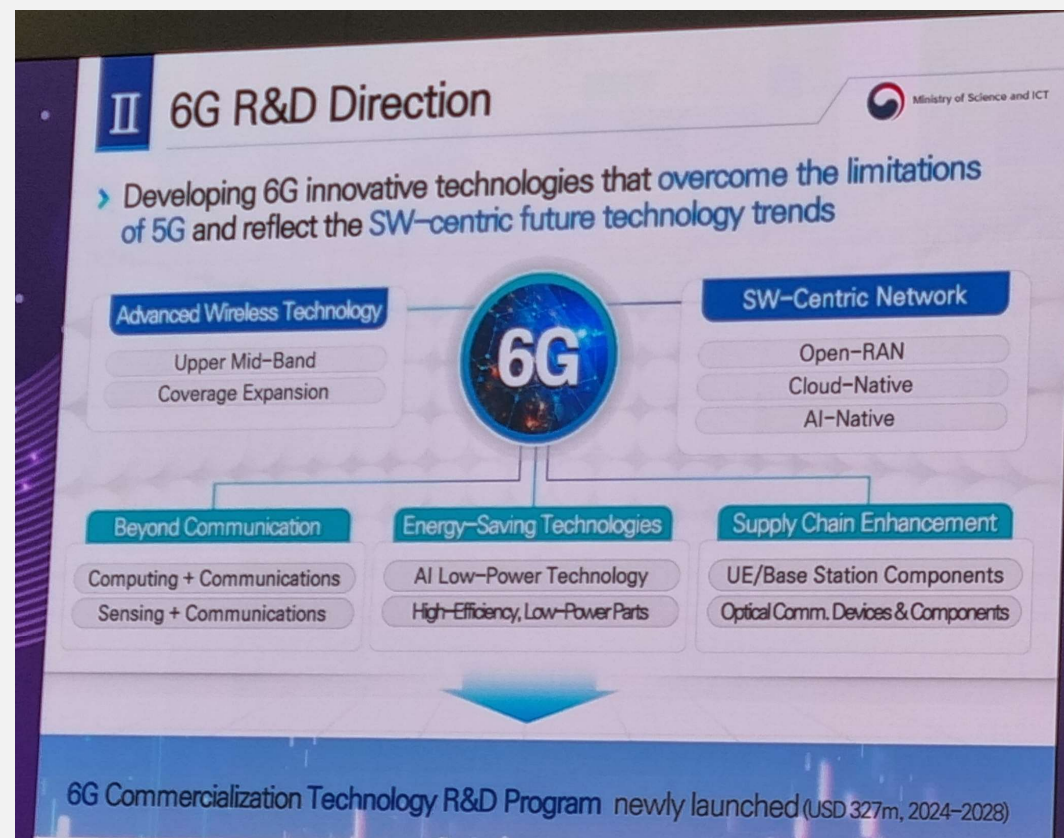
O-RAN GLOBAL PLUGFEST FALL 2023

- ❖ **O-RAN Global PlugFest Fall 2023 takes place at 7 venues**
 - **Japan OTIC: YRP R&D Promotion Committee, NTT DOCOMO, KDDI, SoftBank and Rakuten Mobile in multiple cooperating labs**
 - **LG Uplus in South Korea**
 - **SK Telecom in South Korea**
 - **Digital Catapult in London, UK**
 - **EURECOM, i14y Lab, Orange, Telefónica, TIM and Vodafone across 6 European labs**
 - **CableLabs in Louisville, CO, USA**
 - **University of New Hampshire across 3 labs**

6G R&D DIRECTION

❖ 6G R&D Direction

- **Advanced Wireless Technology**
 - Upper Mid-band
 - Coverage Expansion
- **SW-Centric Network**
 - Open-RAN
 - Cloud-Native
 - AI-Native





**THANK
YOU**