O-RAN Tutorial: What is the buzz all about?

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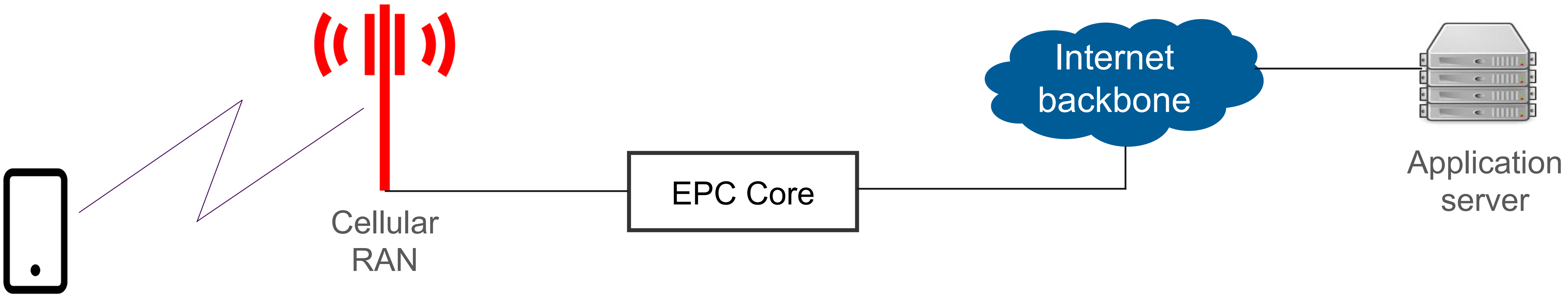
Introduction

LTE Traditional mobile network – RAN and core components

- RAN, core networking and application layer components inter-operate with each other using protocol and standards

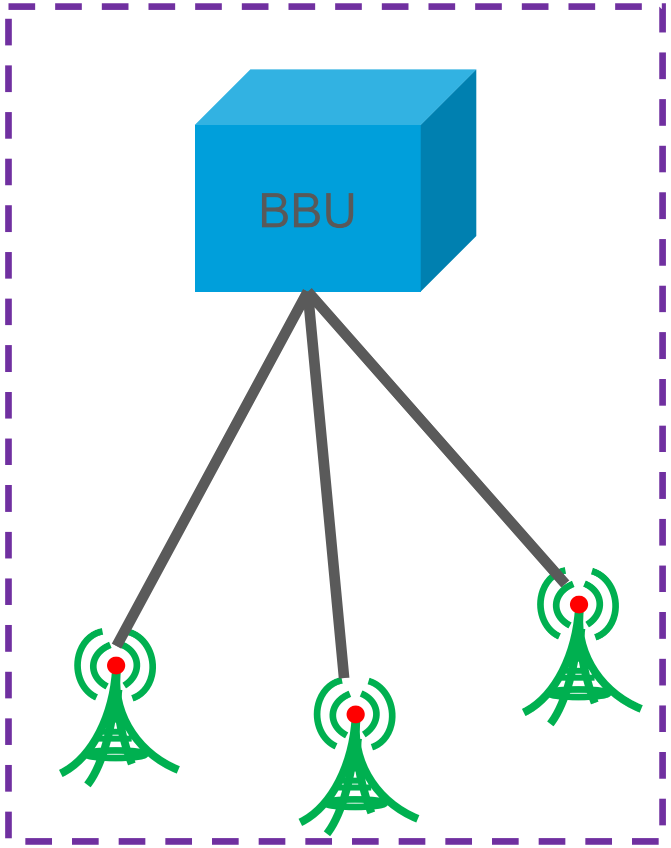
- Cellular RAN base station (or eNB in LTE) has the NFs of the RAN protocol stack layers and radio head antennae for transmission

- Connected to packet core (EPC core) networking components (S-GW/P-GW, HSS, MME). EPC is connected to the internet and further to the application server. Server uses transport layer protocols (TCP/UDP/QUIC)



Traditional cellular RAN


4G LTE
eNB



Monolithic building blocks in traditional RAN

Cellular RAN baseband unit and radio heads at the same integrated physical cell-site (eNB in 4G LTE, gNB in 5G NR)

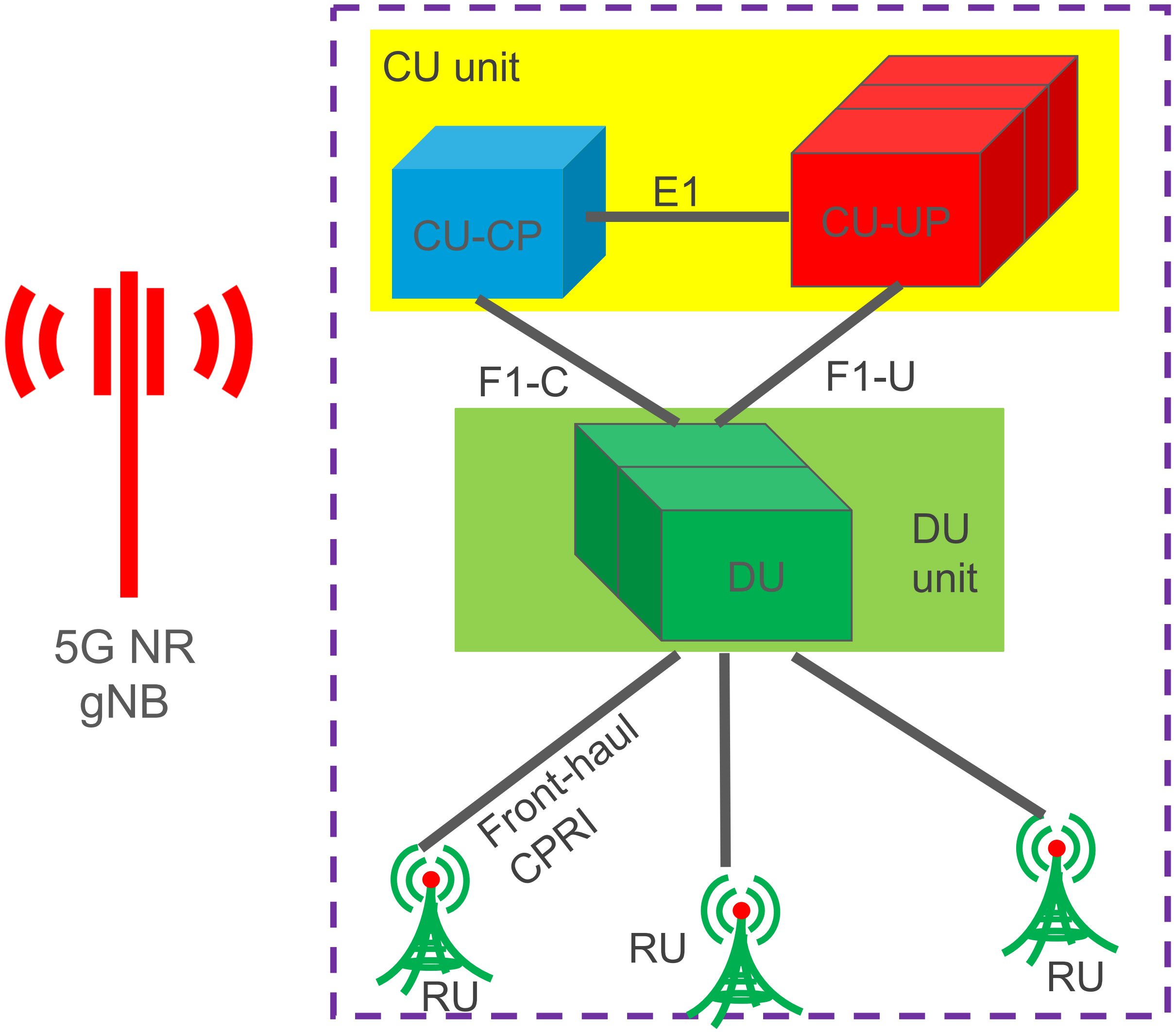
BBU takes care of NFs for the layers across RAN protocol stack and transmission via radio heads

Costly deployment, as every BBU is deployed in each integrated physical cell-site

Proprietary black box software implementation of the RAN protocol stack layers in proprietary hardware

No standard logical split. No multi-vendor inter-operability in the RAN

Cellular RAN with CU – DU split



5G RAN disaggregation - Introduces a logical split BBU architecture

Centralized BBU unit (CU) and distributed BBU unit (DU) split over the F1 interface

Centralized unit further split into control plane and user plane. Connected over E1 interface

DU connected to RU via front-haul LLS split

Split architecture – Increased scalability, time granularity and flexibility in implementations

CU-CP	RRC PDCP-C	CU-UP	SDAP PDCP
DU	RLC MAC PHY-U	RU	PHY-L

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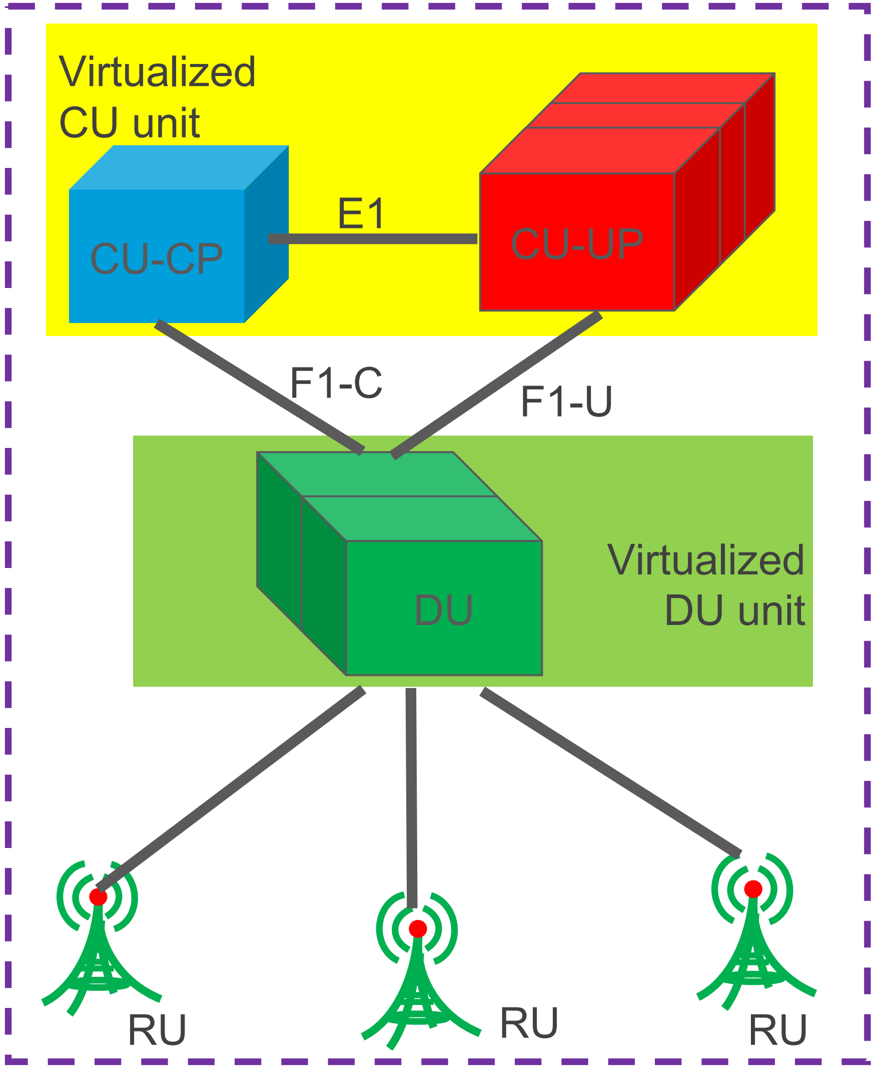
Virtualized RAN



NFs can be moved from proprietary hardware to COTS cloud platforms. Proprietary software implementation with virtualized functions on COTS server

Scalable and cost-effective network deployments from flexible hardware and software implementations

Coordination for better load management/adaptation and real-time performance optimization via logical split

Proprietary interfaces, not necessarily open. Proprietary NFs. Poses challenges to multi-vendor compatibility

Remote Radio unit hardware is proprietary

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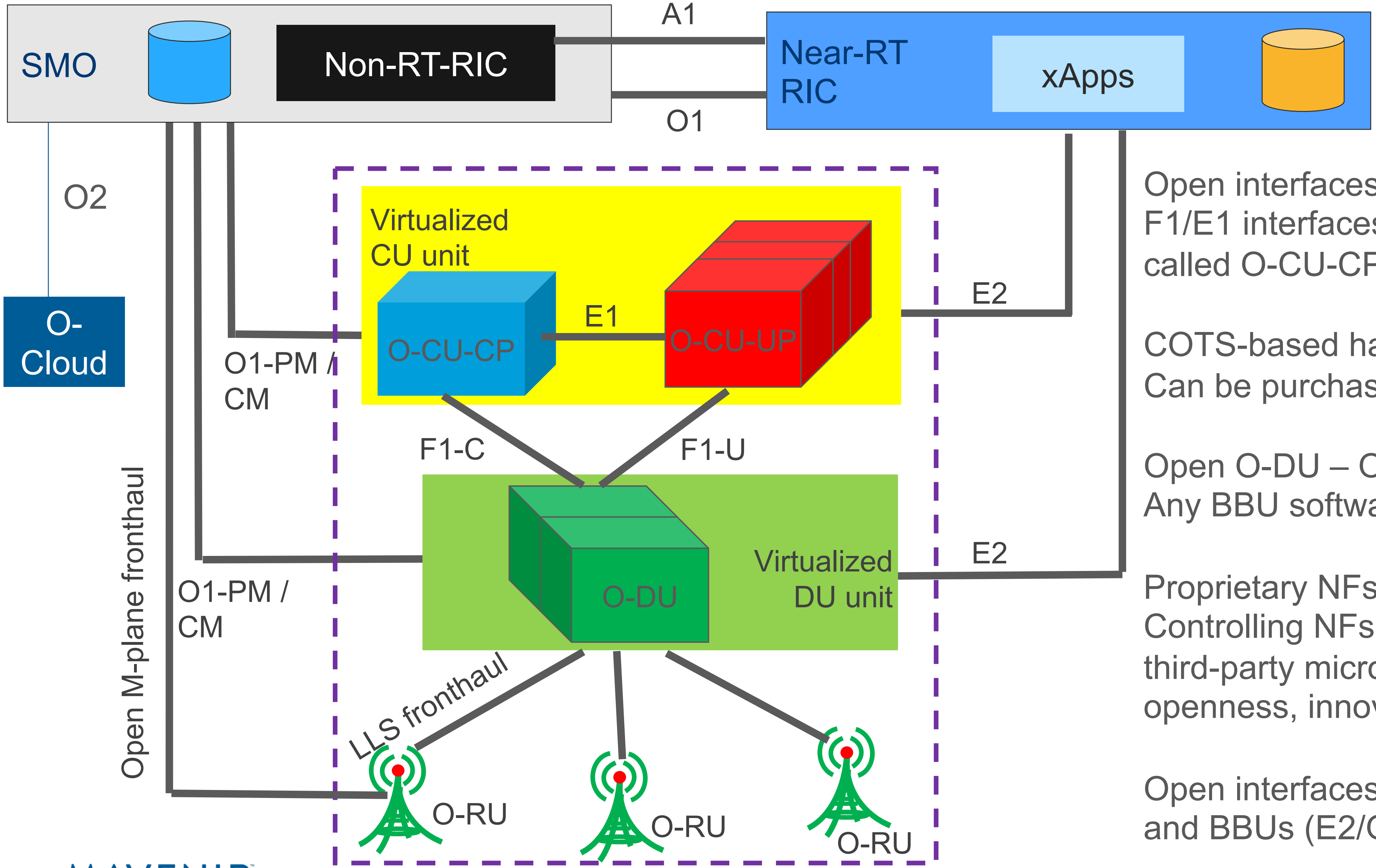
Open RAN



Open interfaces between the BBUs (open-F1/E1 interfaces), O-RAN-compliant, called O-CU-CP, O-CU-UP, O-DU, etc

COTS-based hardware (SDR) for O-RUs. Can be purchased from any RAN vendor.

Open O-DU – O-RU fronthaul interface. Any BBU software can work on hardware

Proprietary NFs inside the BBU. Controlling NFs inside BBU using RIC with third-party micro-services – Paves way for openness, innovation and competition

Open interfaces between RIC components and BBUs (E2/O1/A1)

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Why O-RAN?

RAN Functions and procedures – An Intro

- Functions of RAN protocol stack:
  - Control Plane: Responsible for connectivity, mobility, user context, bearer context-related signaling between the RAN and the mobile User Equipment (UE)
  - User Plane: Responsible for data transfer between the RAN and the UE
  - Management Plane: Responsible for network element configuration of the RAN.

- Layers of the RAN protocol stack manage these functions using procedures and by maintaining relevant UE state information.

- Complex inter-dependencies between the layers of the RAN protocol stack. Intricate network and traffic dynamicity impacts procedures.

RAN Functions and procedures – An Intro

- Procedures are managed by proprietary vendor algorithms. Not necessarily optimal nor data-driven nor programmable.

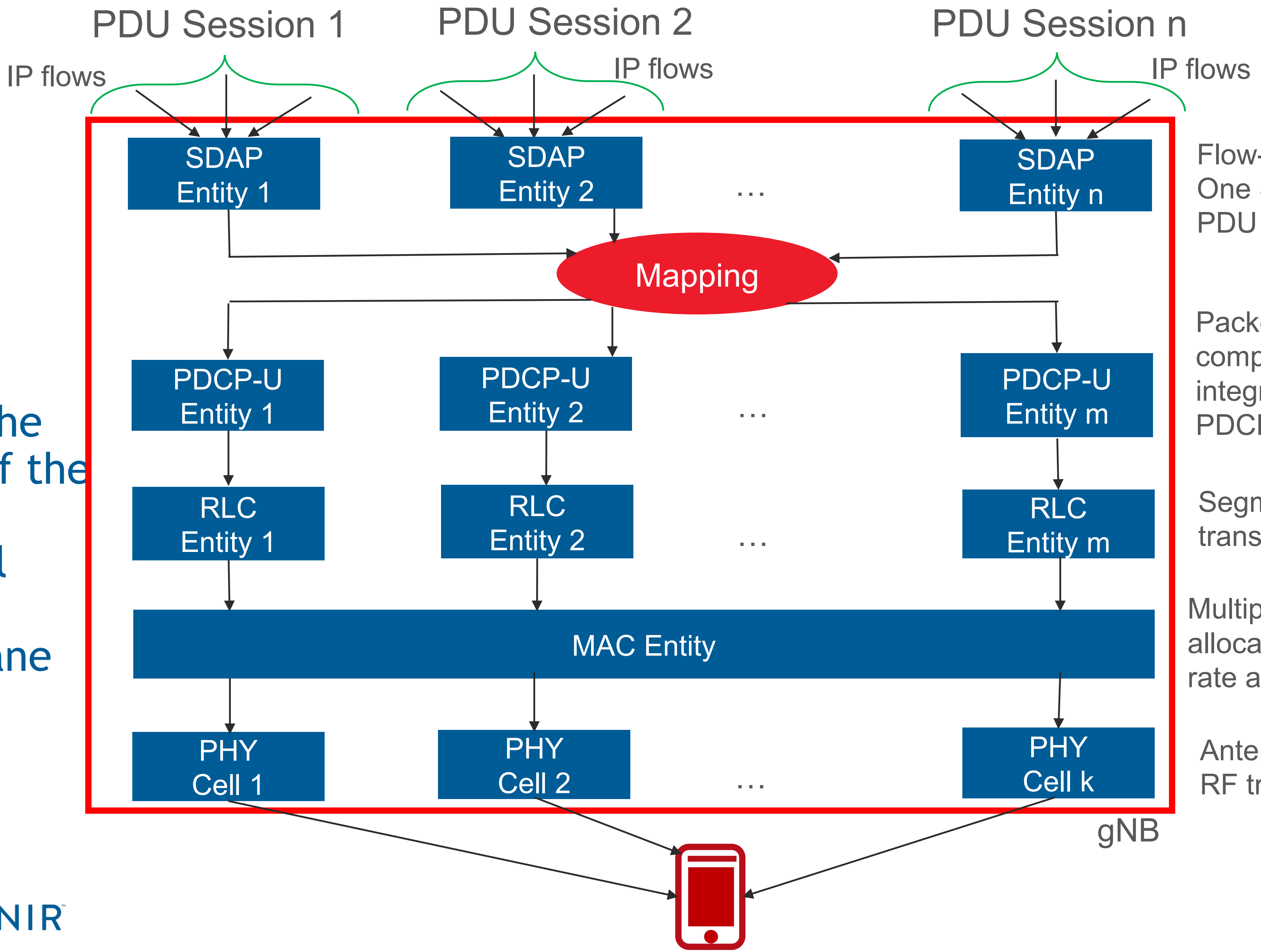
- Vendor-specific proprietary implementation. Challenging to characterize algorithms

- Difficult to quantify intricate inter-dependencies between entities and efficiently capture complex interactions among the layers of the RAN protocol stack

- Optimization of the procedures – Requires unraveling the RAN black box, compute and predict performance of the algorithms using analytics and/or ML/AI.

- SDN principles and open interfaces aid in unraveling the RAN black box and controlling the optimization of procedures

Entities across the layers of the 5G RAN protocol stack – User Plane



Flow-to-bearer mapping. One SDAP entity per PDU session

Packet header compression, ciphering, integrity protection. One PDCP entity per bearer

Segmentation and transmission buffering

Multiplexing, resource allocation and modulation rate adaptation

Antenna propagation and RF transmission

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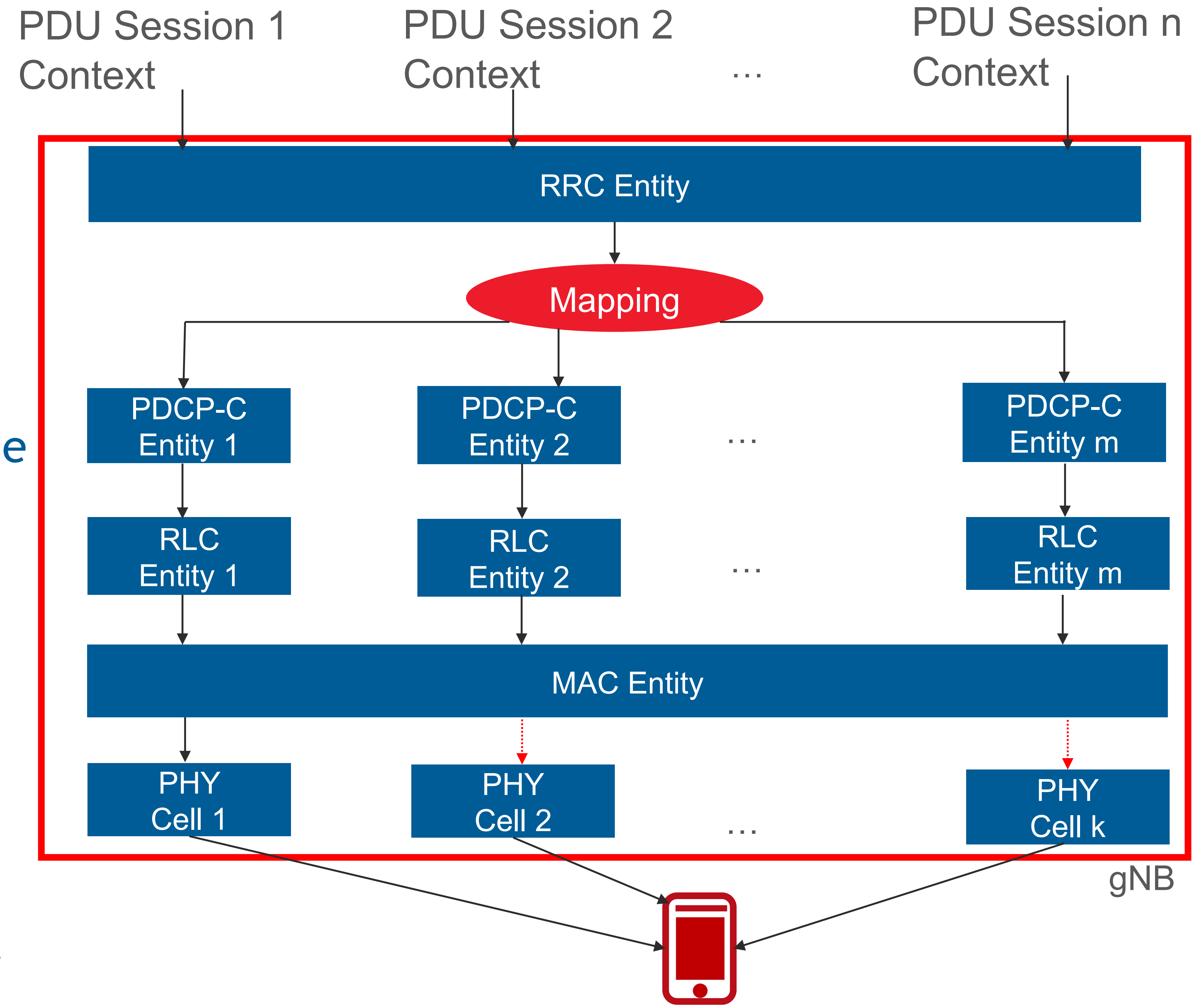
Entities across the layers of the 5G RAN protocol stack – Control Plane



Responsible for UE connectivity and mobility

Packet header compression, ciphering, integrity protection. One PDCP entity per bearer

Segmentation and transmission buffering

Multiplexing, resource allocation and modulation rate adaptation

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Quick re-cap of the RAN mysteries

RRC	Primary and secondary cell selection, connectivity and mobility management, L2 entity configuration	Vendor-proprietary implementation in legacy 3GPP systems Based on the KPI objective or policies set internally by the vendor, the proprietary solutions are implemented by the vendor. No objective, policy or programmable intelligence from 3rd party in legacy systems
SDAP	Mapping QoS flows to data radio bearers	
PDCP	PDCP duplication, multi-RAT traffic split	
RLC	RLC Segmentation, transmission and retransmission buffer management	
MAC	BWP, PRB and TTI allocation – MAC resource allocation, HARQ retransmission	
PHY	RF transmission, MIMO groups, beamforming weights	

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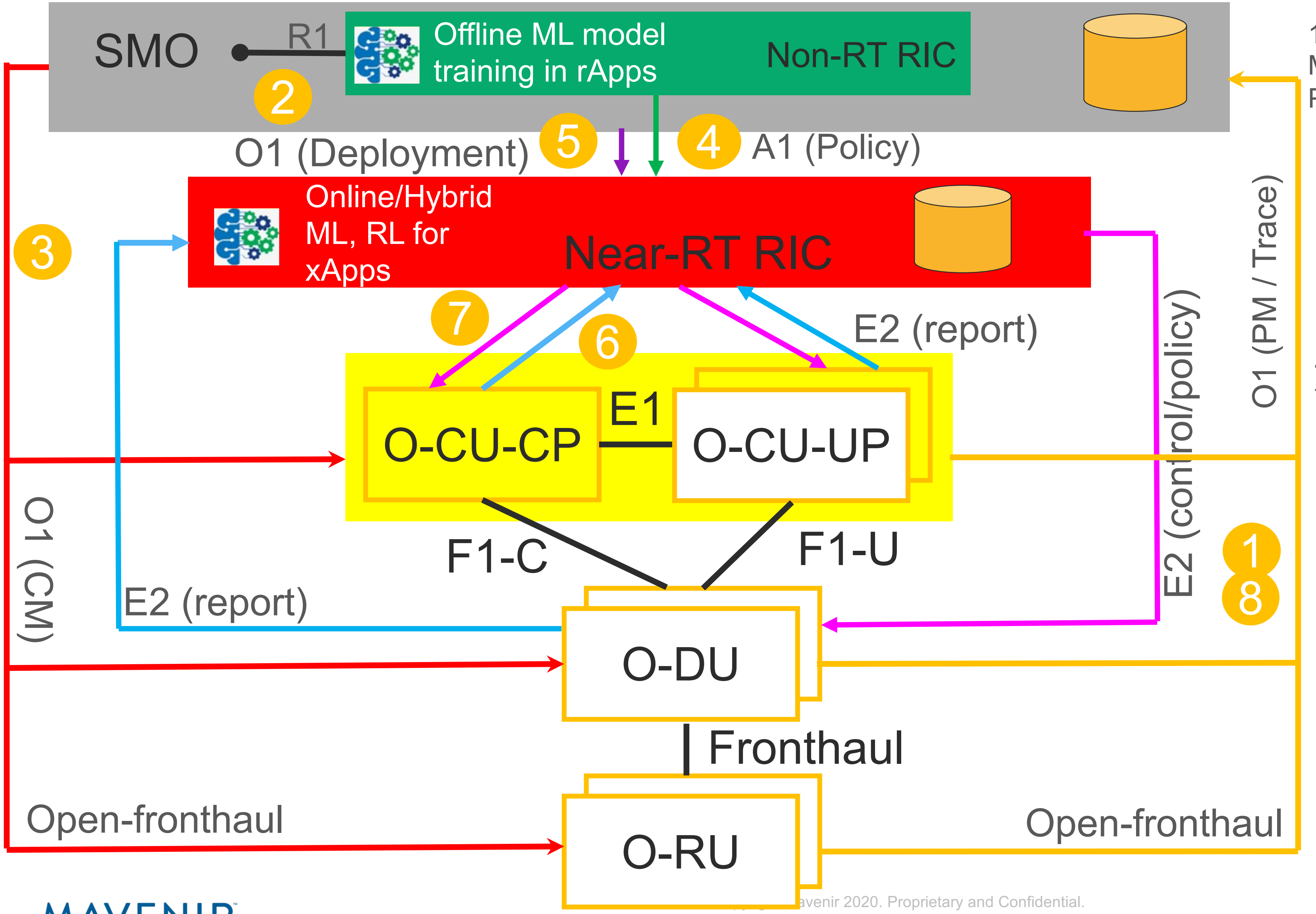
The details and procedures

Flow between hierarchical control loops



1 - Per-UE/per-cell/per-slice Performance Measurement reporting and tracing. Eg: PRB utilization, UE packet delay

2 – Recommendation of config mgmt for per-cell/per-UE/per-slice. Eg: A3 threshold for HO, per-UE MDT tracing periodicity, etc.

3 – Cell/slice-level Config mgmt. and UE-level config for tracing

4 – A1 policy and KPI/RRM guidance from non-RT RIC to near-RT RIC. Eg: per-UE latency prediction, cell-wide PRB utilization constraint

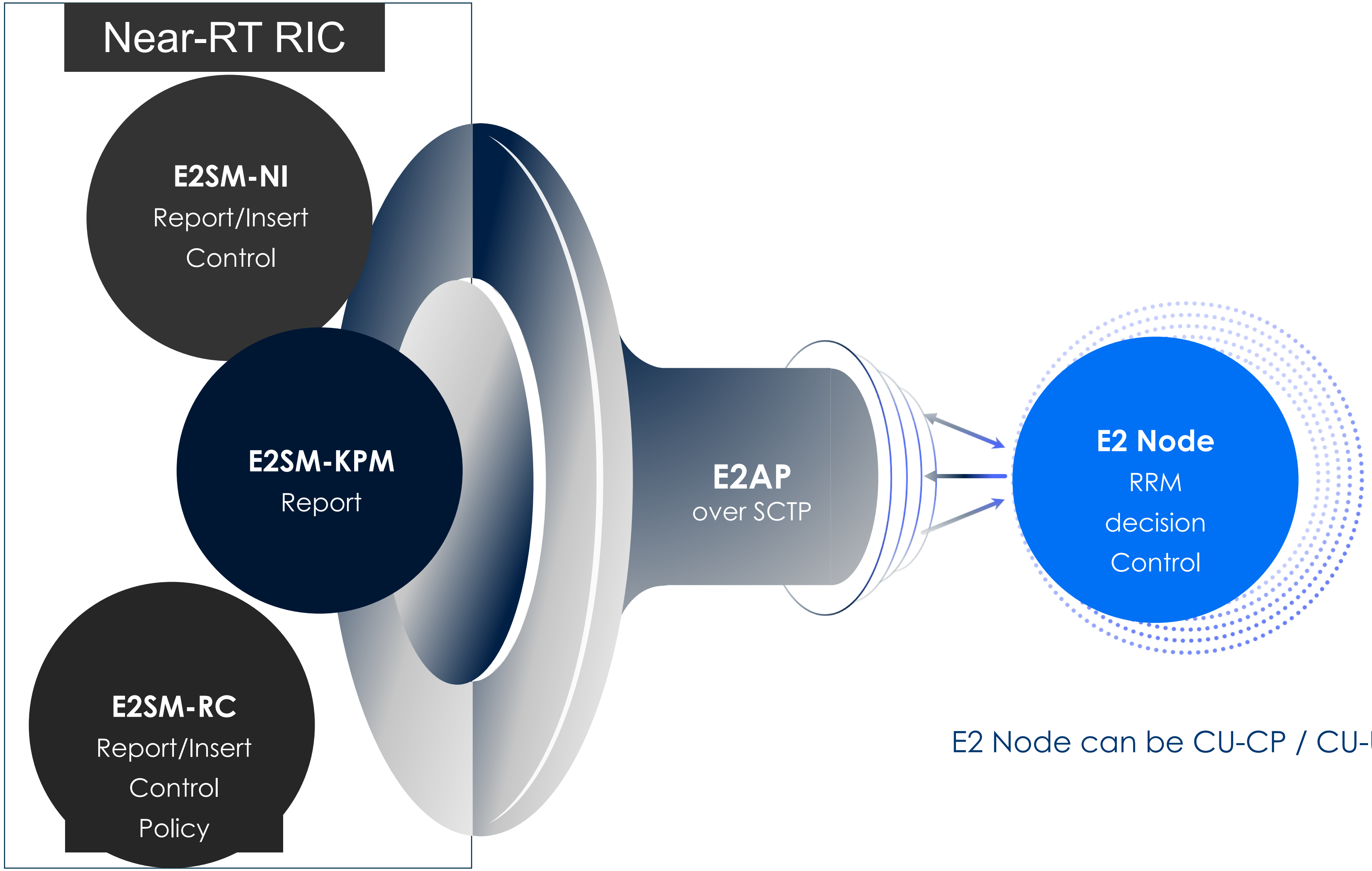
5 – ML model deployment over O1 to near-RT RIC. Eg: deploying RNN/DNN models on latency prediction

6 – Per-UE measurements across the RAN protocol stack layers. Eg: MAC buffer occupancy, RLC segmentation etc.

7 – Per-UE control and imperative policy from the RIC to the RAN. Eg: QoS flow to DRB mapping, DU scheduler

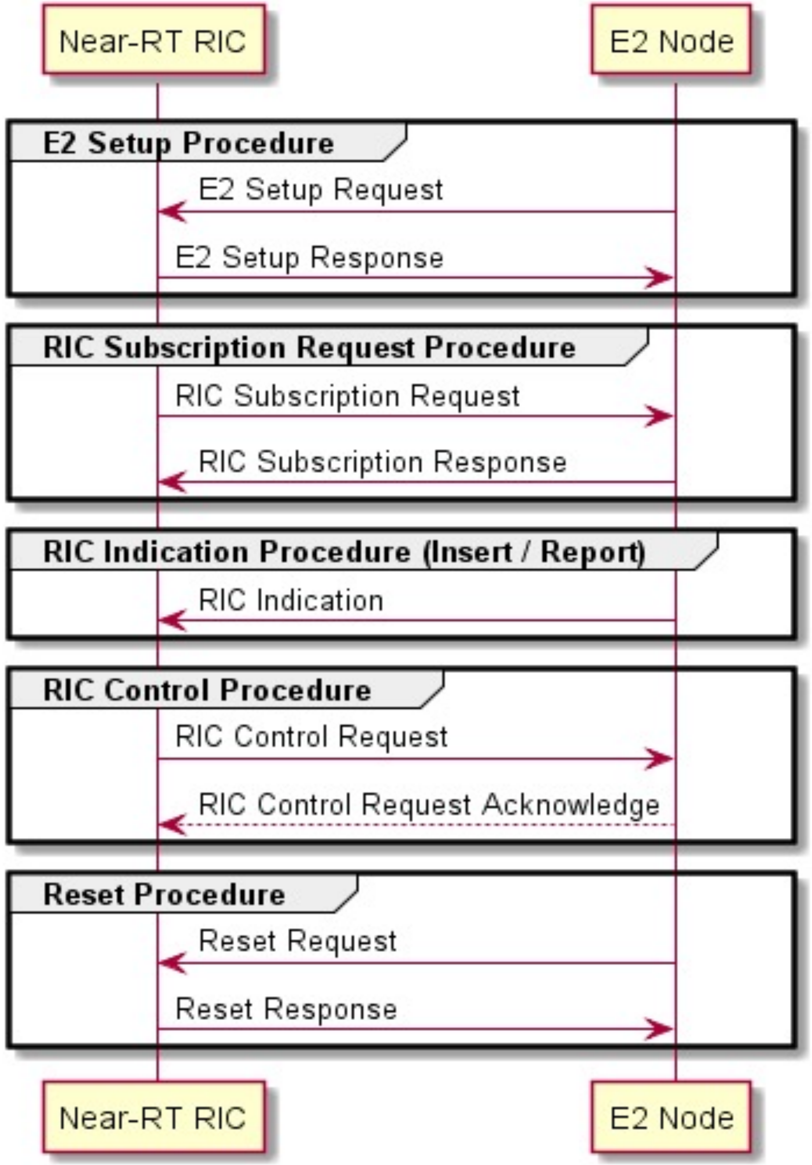
8 – Repeat 1

Near-RT RIC – E2 interface



E2 Node can be CU-CP / CU-UP / DU

Examples of E2AP procedures



E2 Service Models

1. E2SM-NI
   Tracing of UE-associated signaling messages exchanged over network interfaces at the RIC

2. E2SM-KPM
   To send UE-specific, cell-specific and node-specific RAN PMs defined in O-RAN WG3 from the E2 node to Near-RT RIC

3. E2SM-RC
   To enable the E2 node request the RIC to control RAN functionalities, and to facilitate the RIC in controlling the RAN

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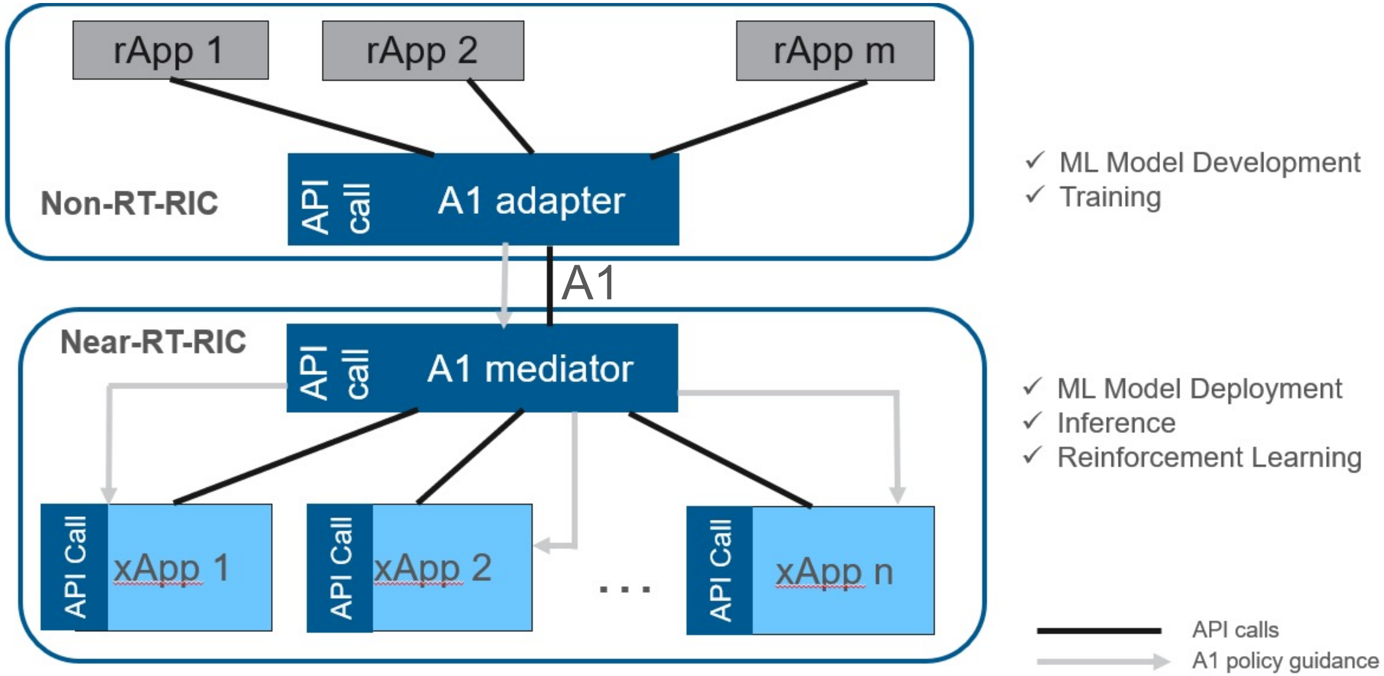
What is provisioned over the A1 interface?

> A1 Policy (KPI targets and objective functions) from non-RT RIC to near-RT RIC

> A1 Policy Guidance/resources from non-RT RIC to near-RT RIC

> A1 Enrichment Information from non-RT RIC to near-RT RIC

> UE-level, UE group-level, slice-level, cell-level



> Cell-level declarative policies:

– Policy on maximum DL PRB usage, maximum UL PRB usage, maximum number of RRC connections, list of cells to share the load of a given cell

> UE-level/UE-group-level/slice-level declarative policies:

- Policy on UE throughput (UL/DL), UE packet delay (UL/DL), packet loss rate (UL PDCP/DL RLC), reliability (DL/UL)

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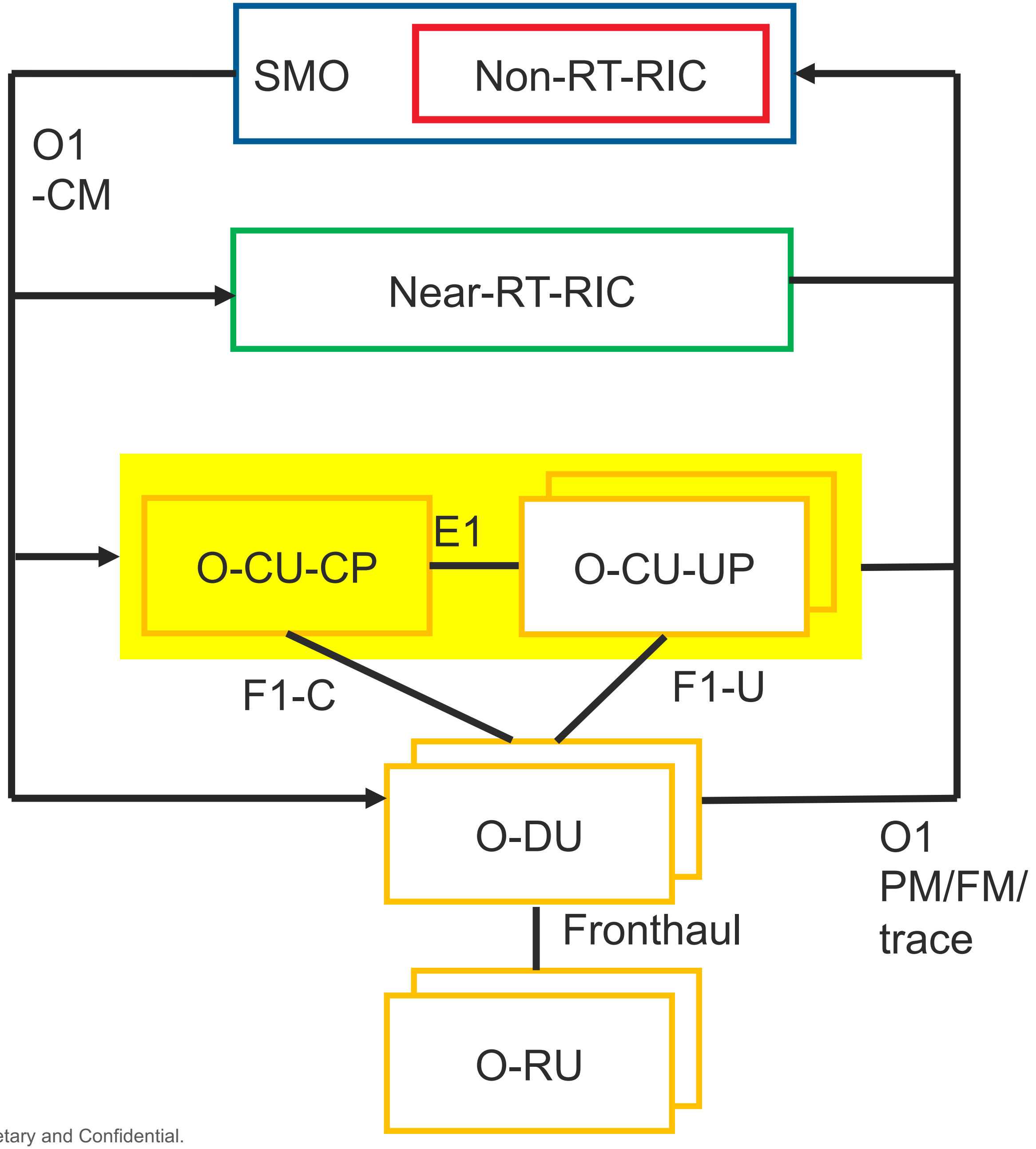
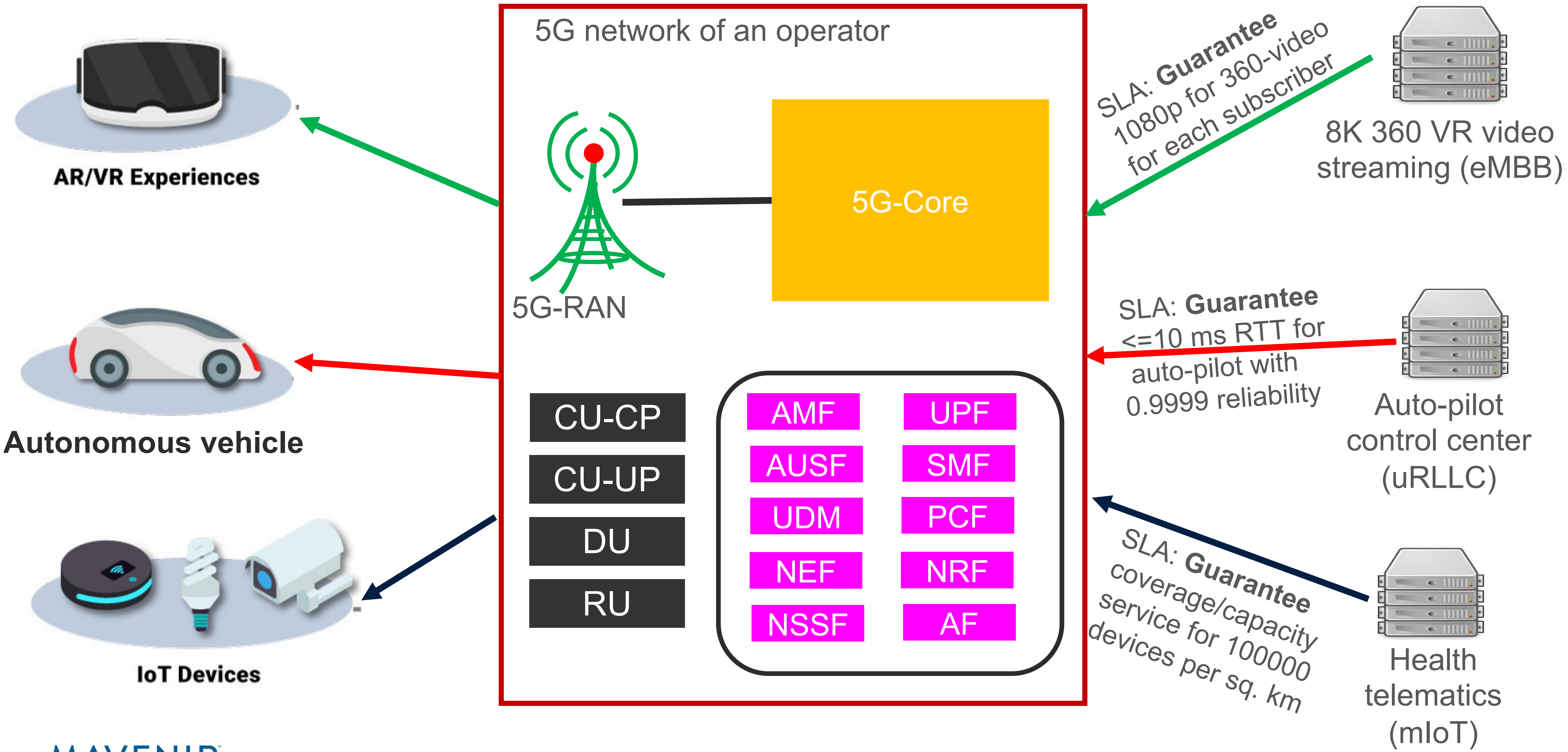
What is provisioned over the O1 interface?

- O1 cell-level call tracing and UE-level MDT tracing (from O-RAN nodes to the SMO)
- O1 cell-level and UE-level Performance Measurement Reporting (from O-RAN nodes to the SMO – TS 28.552)
- O1 cell-level Configuration Management and UE-level tracing configuration (from SMO to O-RAN nodes – TS 28.541, TS 28.622)
- O1 fault management – alarms/notification (from O-RAN nodes to SMO)



Use-case Applications

Slicing



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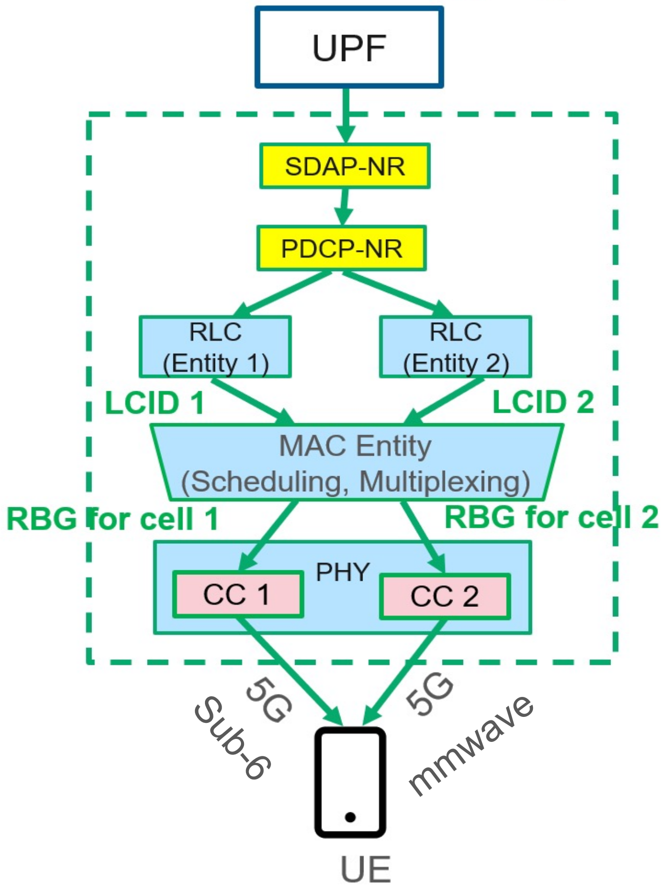
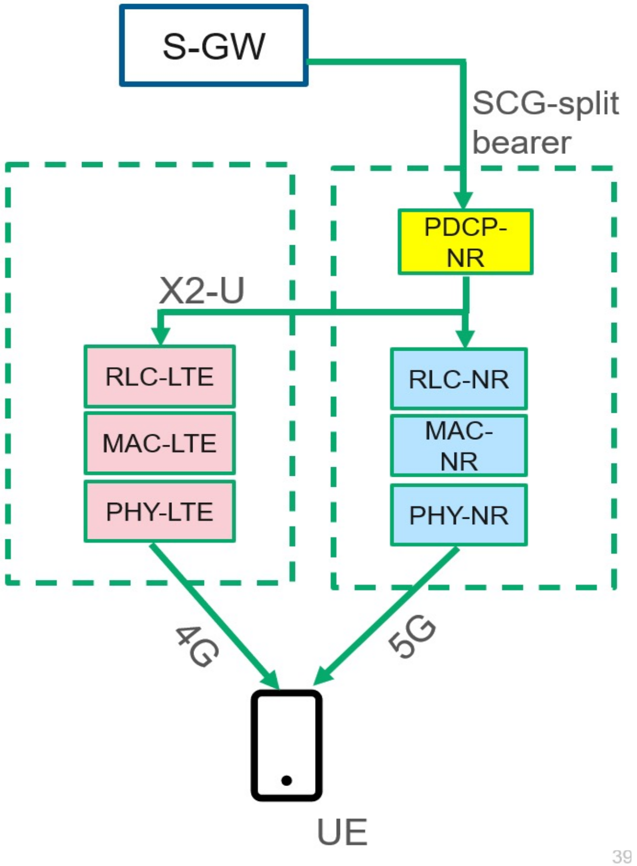
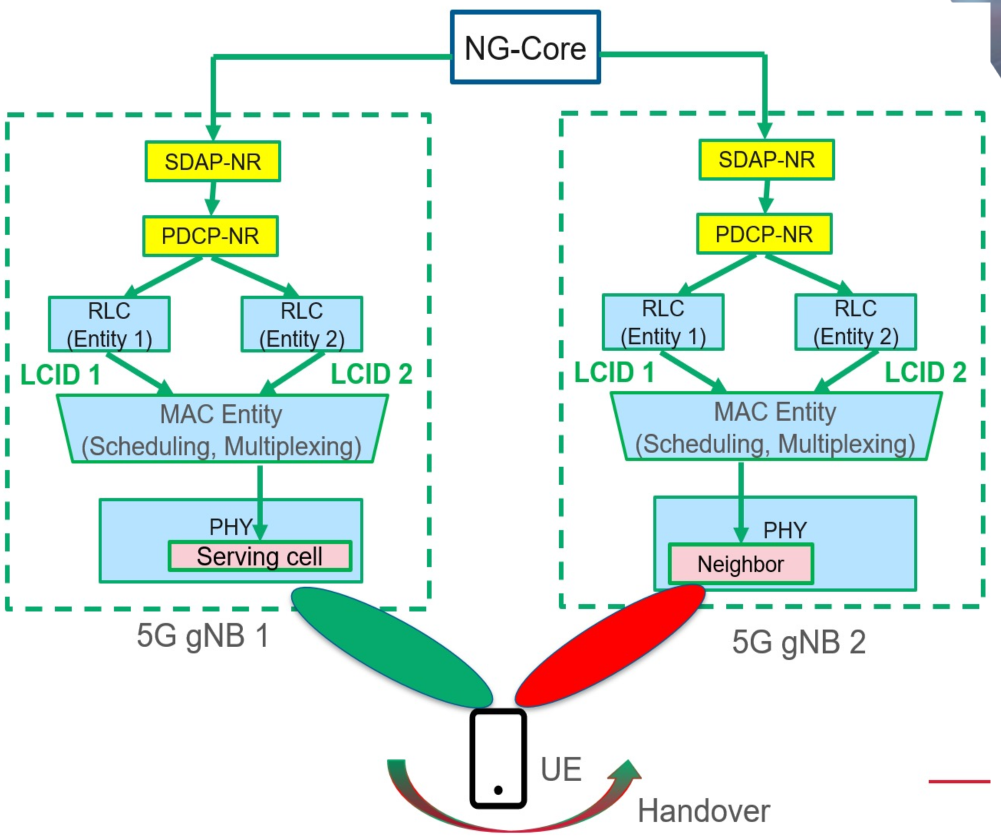
Traffic Steering feature



Carrier Aggregation and band switching

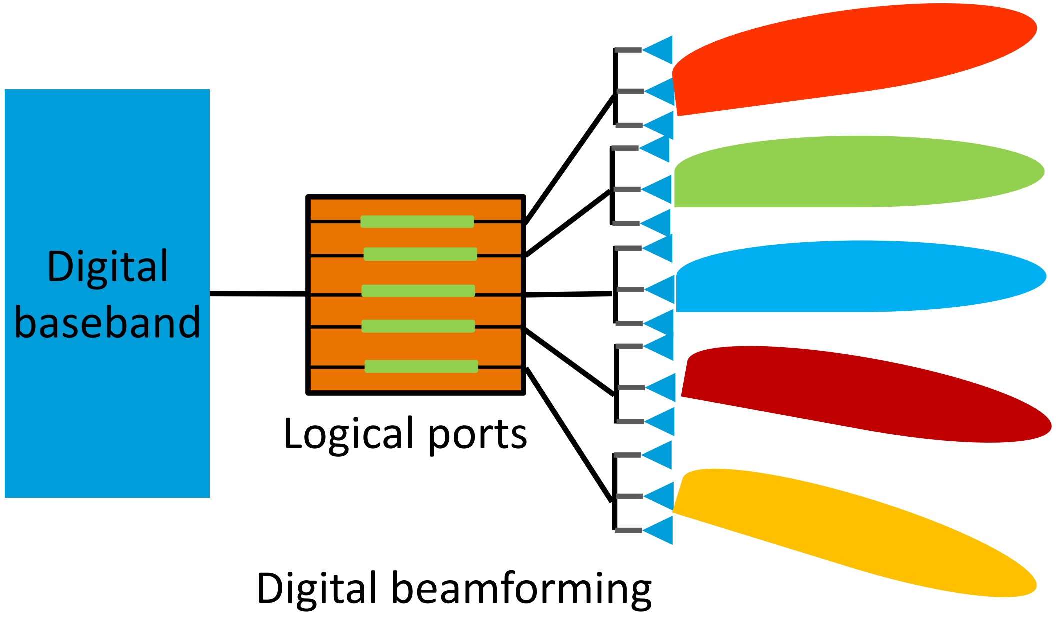


Multi-RAT dual connectivity



Connected Mode Mobility

Multi-user and massive MIMO Beamforming



- 32x32, 64x64 antenna ports
- Signal is precoded in the baseband processing before RF transmission
- Transmission on the same PRB/TTI set to different UEs
- Mapping between antenna elements and logical antenna ports
- Multiple beams (one per UE) formed simultaneously through antenna ports
- Spatial multiplexing and UE diversity
- *Which UEs in a MU-MIMO group?*
- *How many independent streams/layers of data?*
- *Beamforming weights per UE.*
- *Channel estimations for a UE. Unrealistic to expect full channel feedback from UE to RAN*

Miscellaneous

Mavenir RIC design

1. Cloud Native
2. Deployed on Kubernetes clusters
3. Microservices-based
4. Supports public cloud like AWS
5. Supports cloud-native gRPC
6. Supports O-RAN-SC RMR
7. E2SM-RC compliance
8. E2SM-KPM compliance
9. Integrated ML/RL framework
10. E2AP compliance

First standards-compliant Near-RT RIC controlling the RAN

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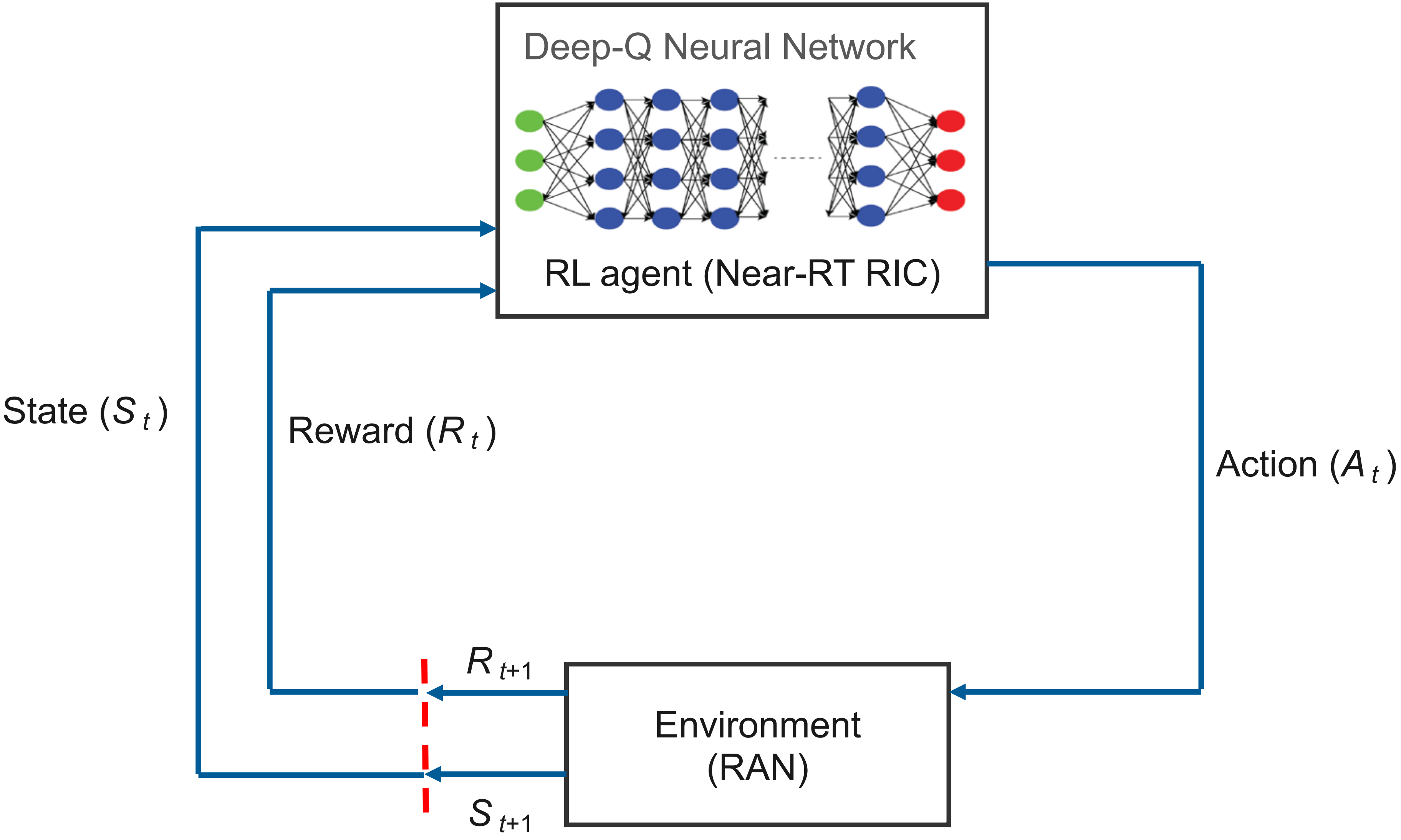
Integrated ML/RL framework in RIC



O-RAN alliance WGs

- WG1: O-RAN architecture and use-cases
- WG2: Non-RT RIC, A1/R1
- WG3: Near-RT RIC, E2
- WG4: Open fronthaul
- WG5: Open Interfaces (Xn, X2, F1, E1, W1)
- WG6: Cloudification and Orchestration
- WG7: White-box hardware group
- WG8: Stack Reference Design Workgroup
- WG9: Open X-Haul Transport.
- WG10: OAM for O-RAN

- OSFG : Open Source Focus group
- SDFG: Standard Development Focus Group
- TIFG: Test and Integration Focus Group
- SFG: Security Focus Group

- O-RAN Software Community

Conclusion

1. Introduction to O-RAN
2. Why O-RAN
3. Details and procedures
4. Use-cases
5. O-RAN alliance WGs

Come! Let’s unravel the RAN mystery….