19-21 JULY 2022, VOLOS, GREECE
SLICES-SC Summer School

SD-RAN Project

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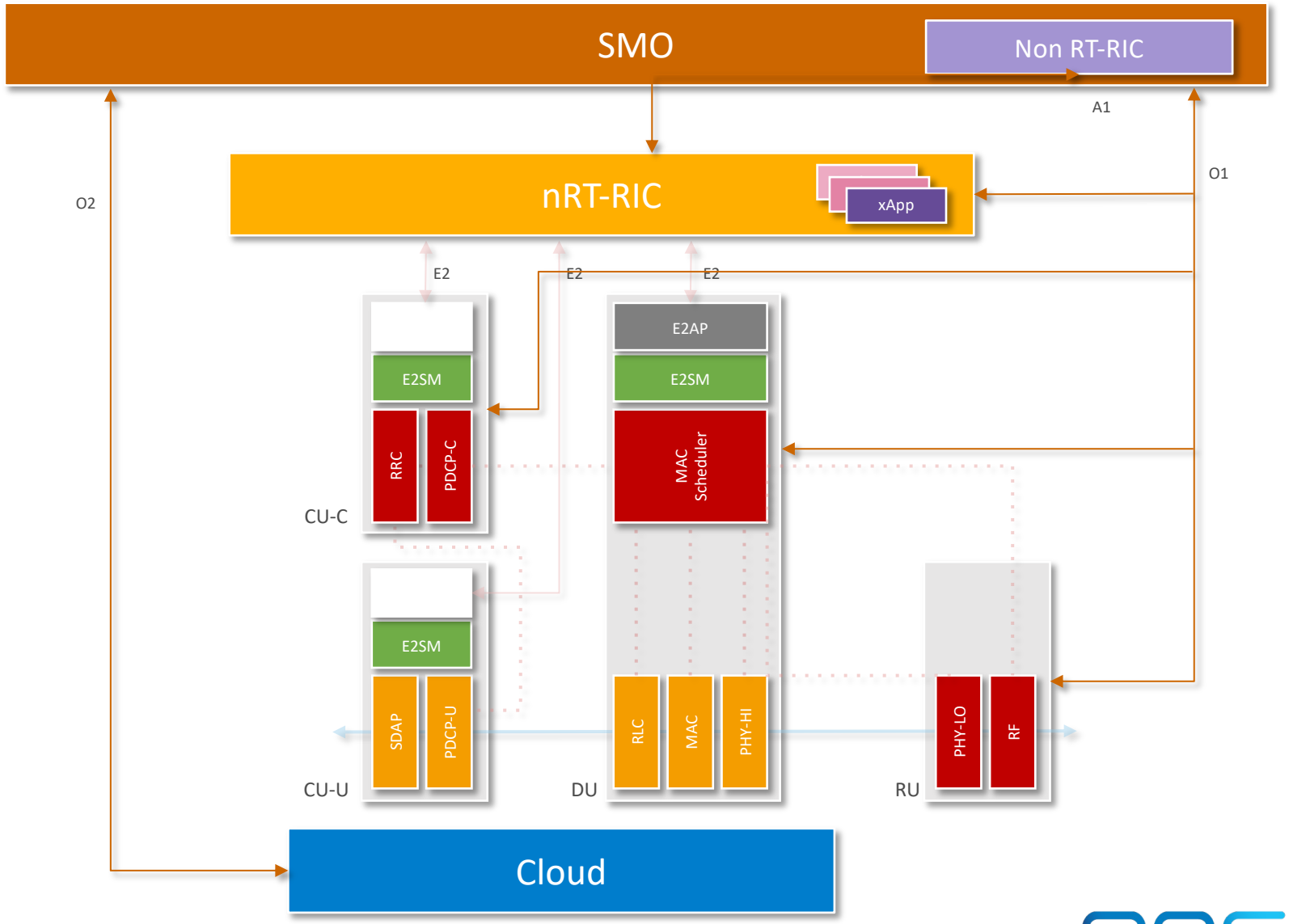
Introduction

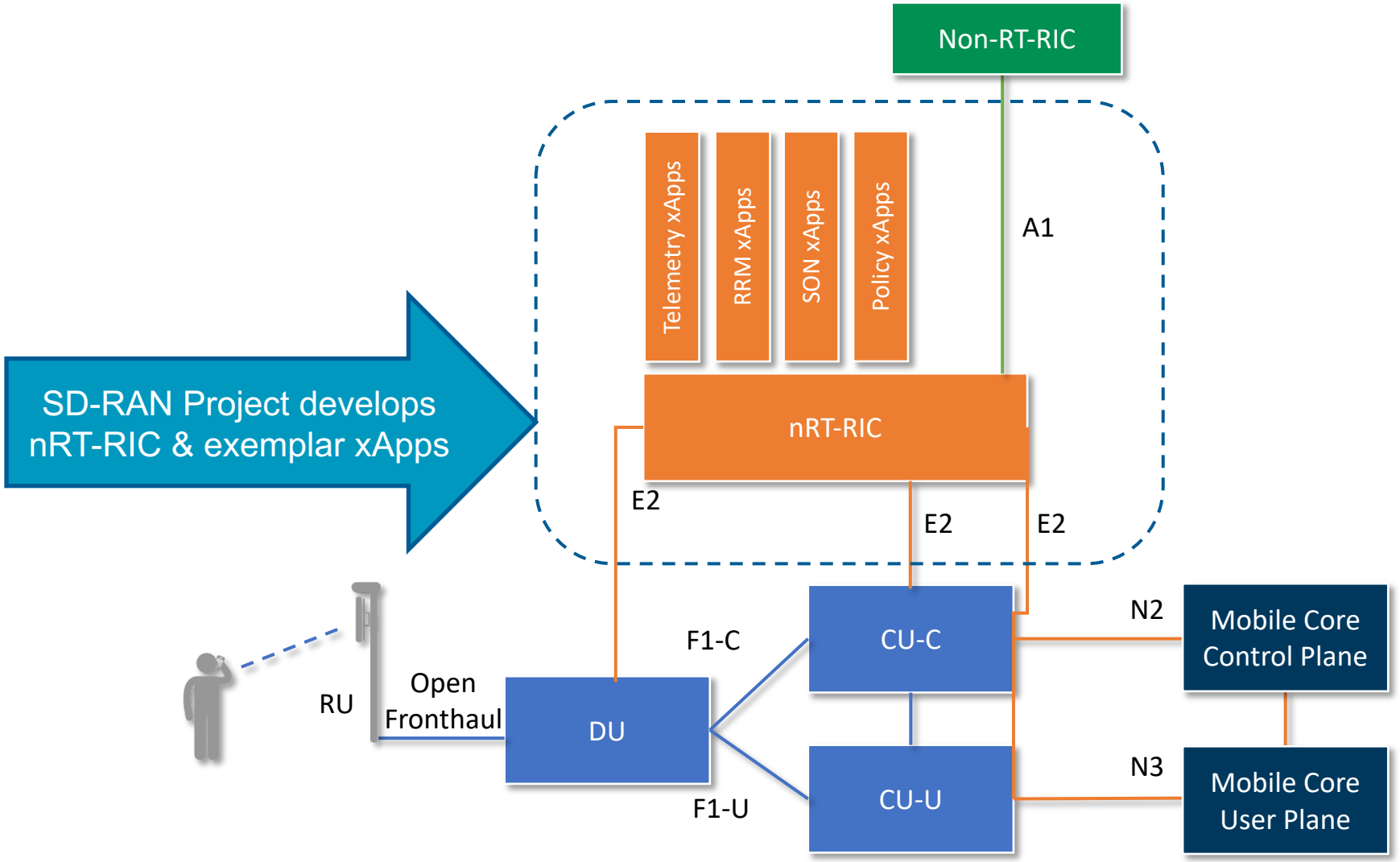
A compilation of resources from different presentations
(SD-RAN community calls, SD-RAN Trial in DT, O-RAN PlugFest)
Thanks to all the SD-RAN team and community!

O-RAN Interfaces (O1, O2, A1, E2)

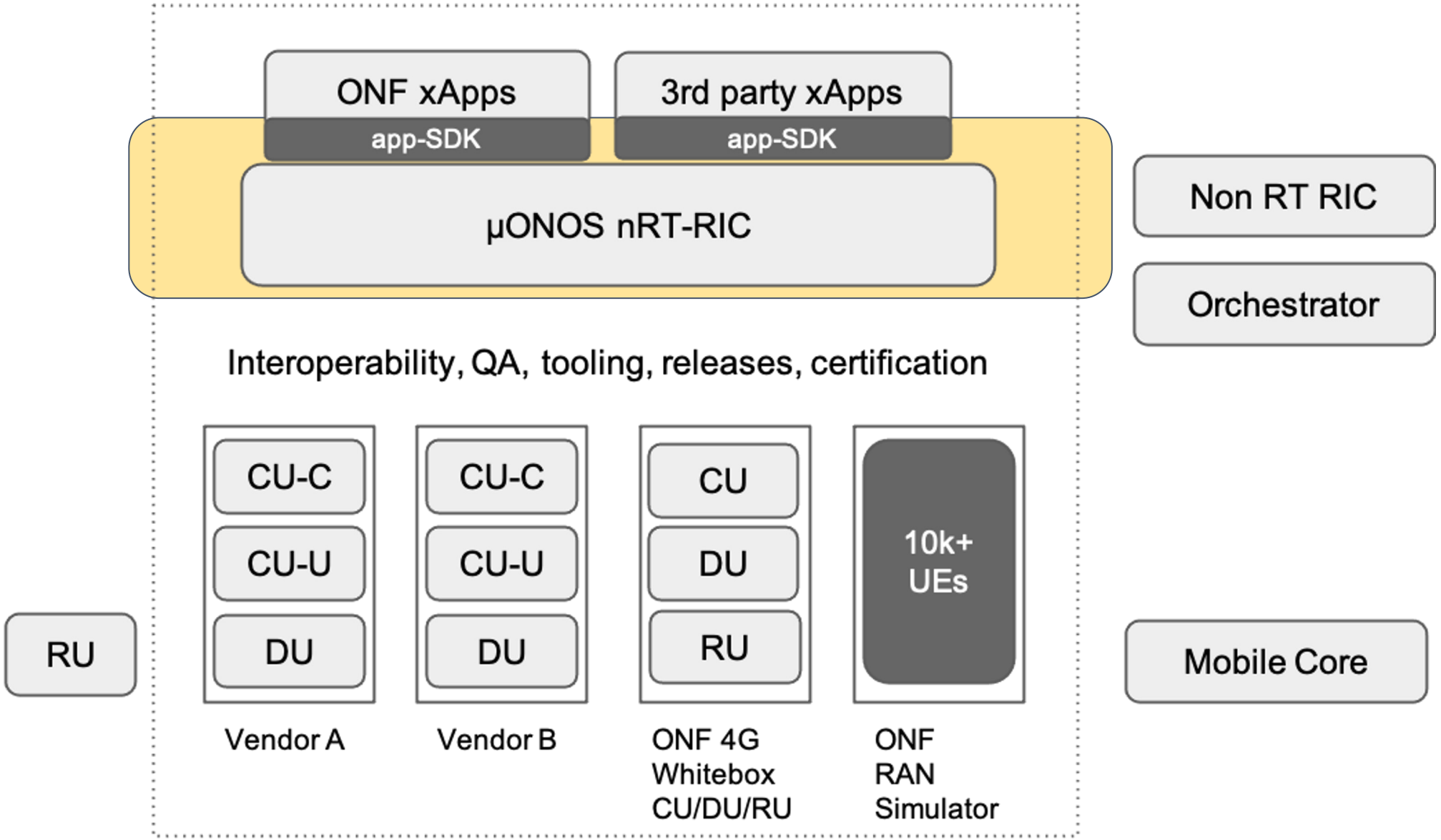
- E2AP defines the general protocol by which the nRT-RIC and disaggregated E2 Nodes communicate.
  - Action Types: Report, Insert, Policy, Control
- E2SMs are “contracts” between an xApp and the E2 Node. They define function specific protocols that are implemented on top of the E2AP specification.
- The implementation of a given E2SM on the gNB side requires explicit feature and interface development / stack enhancements



SD-RAN Architecture

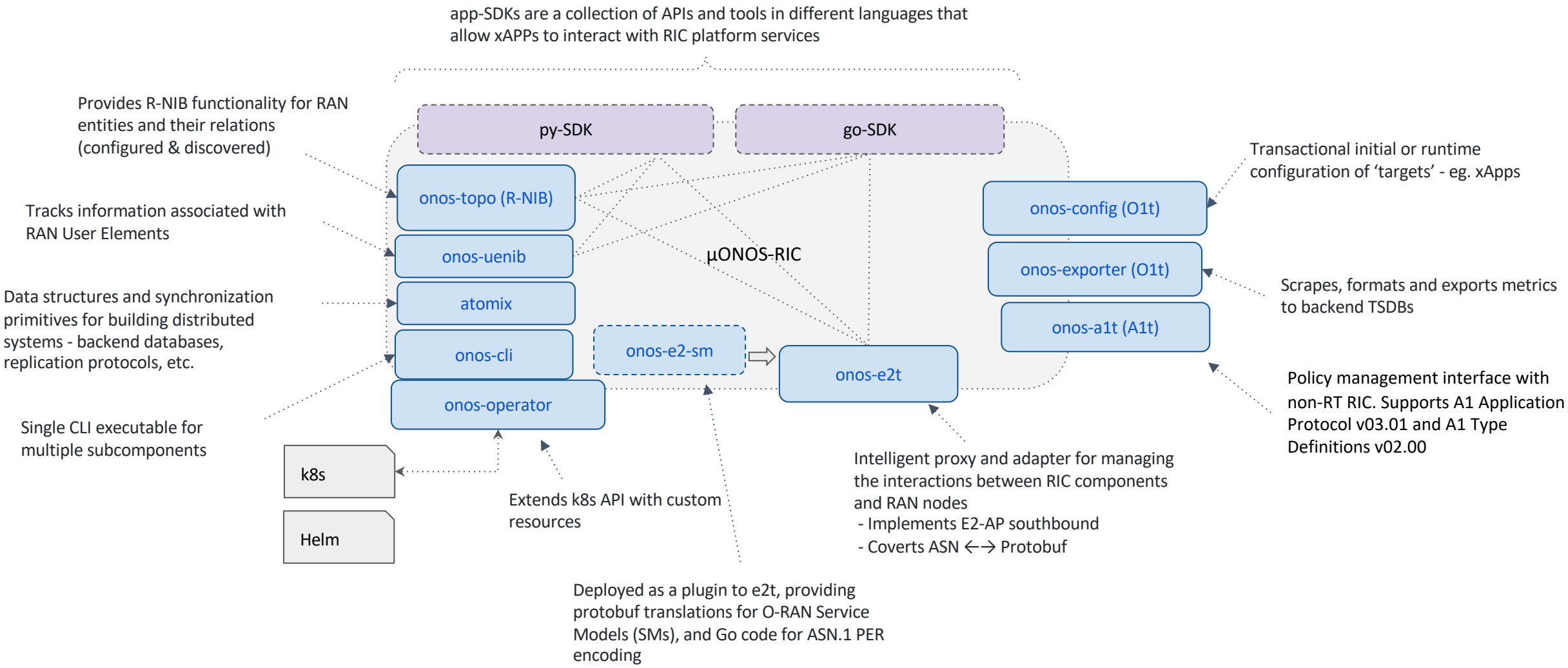


SD-RAN Project



SD-RAN's µONOS-based nRT-RIC

cloud-native microservices architecture



The SDKs

RIC abstraction layer

SDK APIs

SDK Implementation

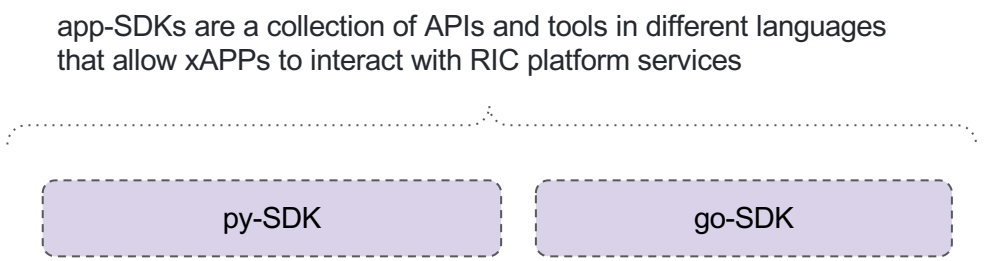
libraries (e.g. asyncio, Prometheus, HTTP …)

test framework

logging framework

code samples/guides

tools for ease of deployment/development

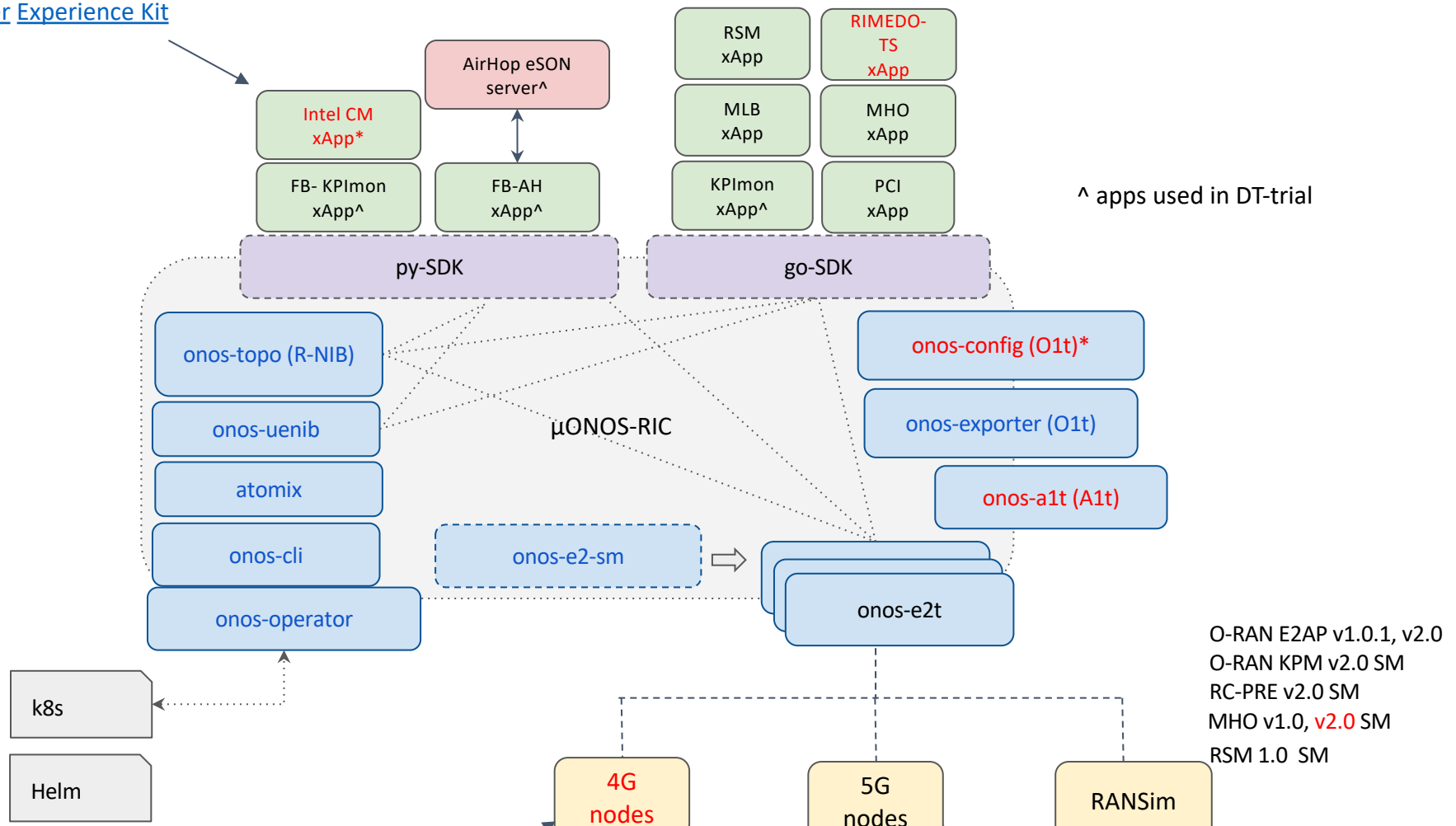


SD-RAN Releases

- SD-RAN v1.0 Released December, 2020
  - Featured first e2e release consistent with O-RAN architecture
    - RIC & KPM-xApp + RAN-hardware & software (E2 nodes) + Mobile-core
  - Beginnings of the Go app-SDK
  - Introduced sdRan-in-a-Box (RiaB) - completely virtualized e2e dev/test environment
- SD-RAN v1.1 Released March, 2021
  - Featured successful integration with commercial xApp - AirHop's eSON server
  - Introduced Python app-SDK contributed by Facebook
  - Developed new use-case - PCI conflict resolution via pre-standard Service Model - RC-PRE
  - Introduced O-RAN compliant RAN simulator (RANSim) with E2AP, SMs etc
- SD-RAN v1.2 Released July, 2021
  - Featured successful integration with commercial 5G-NR RAN software (CU/DU) from Radisys
  - Introduced new use-case implementation - Mobility Load Balancing
  - Addition of Radio and User-Element Network-Information-Bases (R-NIB & UE-NIB) to RIC platform
  - Part of DT-Trial in Berlin
- SD-RAN v1.3 Released Oct, 2021
  - RAN Slicing (4G) & Mobile Handover - new use cases
  - RIC e2T clustering for HA and Scale
  - Upgrade to O-RAN E2AP 2.0

SD-RAN v1.4

See Intel Smart Edge Open Developer Experience Kit



^ apps used in DT-trial

O-RAN E2AP v1.0.1, v2.0
O-RAN KPM v2.0 SM
RC-PRE v2.0 SM
MHO v1.0, v2.0 SM
RSM 1.0 SM

RAN Slicing (UL+DL)
Demo @ Sept 2nd Community Call

Discussion @ Feb-17th Community Call

SD-RAN v1.4

Use Case	xApps	Service Model (developed by)	Radisys disaggregated 5G SA CU/DU	Sercomm 5G-SA gNB	Whitebox LTE CU/DU	RANSim
KPI Monitoring	onos-kpimon, fb-kpimon, fb-ah	KPM v2 (O-RAN)	E2-AP v1.0.1	E2-AP v1.0.1	E2-AP v2.0	E2-AP v2.0
PCI Conflict Resolution	onos-pci, fb-ah	RC-PRE v2 (ONF / FB / AirHop / Radisys)	E2-AP v1.0.1			E2-AP v2.0
Mobility Load Balancing (MLB)	onos-mlb, fb-ah	RC-PRE v2 (ONF / FB / AirHop / Radisys)	E2-AP v1.0.1			E2-AP v2.0
Mobile Handover (MHO)	onos-mho, Intel CM-xapp	MHO v1 (ONF/FB/Intel)				E2-AP v2.0
RAN Slice Management	onos-rsm	RSM v1 (ONF)			E2-AP v2.0	
Policy driven Traffic Steering	rimedo-ts	MHO v2 (ONF/FB/Intel/Rimedo-Labs)				E2-AP v2.0

Mobility Load Balancing (MLB)

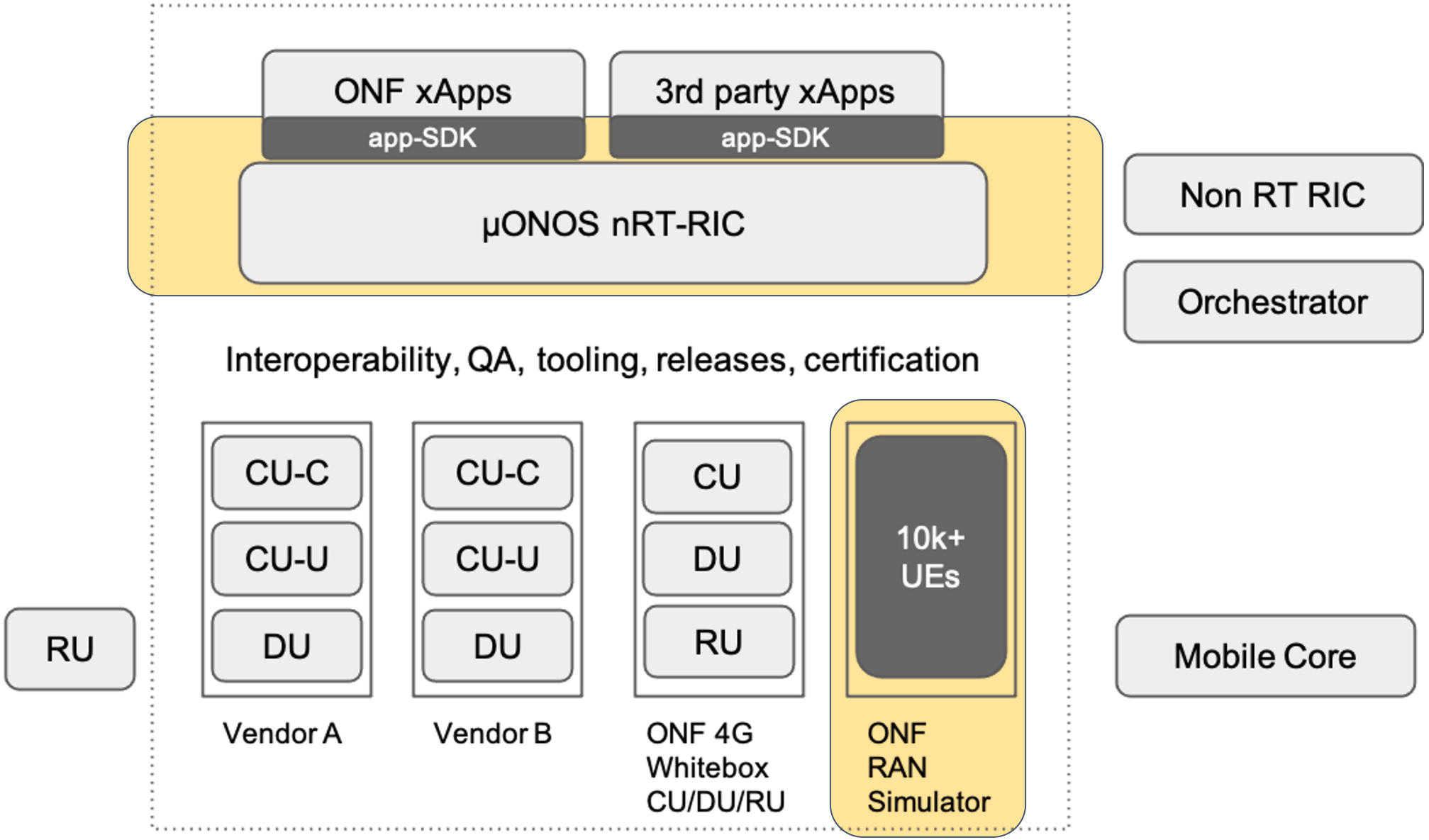
- CU makes Handover decision. xApp & RIC influences A3 event generation from UEs
- Use case requires KPM and RC-PRE Service Models to determine cell load, cell neighbors, and make changes to cellIndividualOffset for neighbors
- MLB test application does not subscribe to any SM; instead it leverages information stored in RIC platform by other xApps
- Works with AirHop eSON server & fb-ah-xApp on python app-SDK; xApp subscribes to both SMs
- Works with RANSim in “native” mode
- Works with Radisys 5G SA CU/DU; part of SD-RAN trial at DT
- Part of SD-RAN 1.2 release

Mobile Handover (MHO)

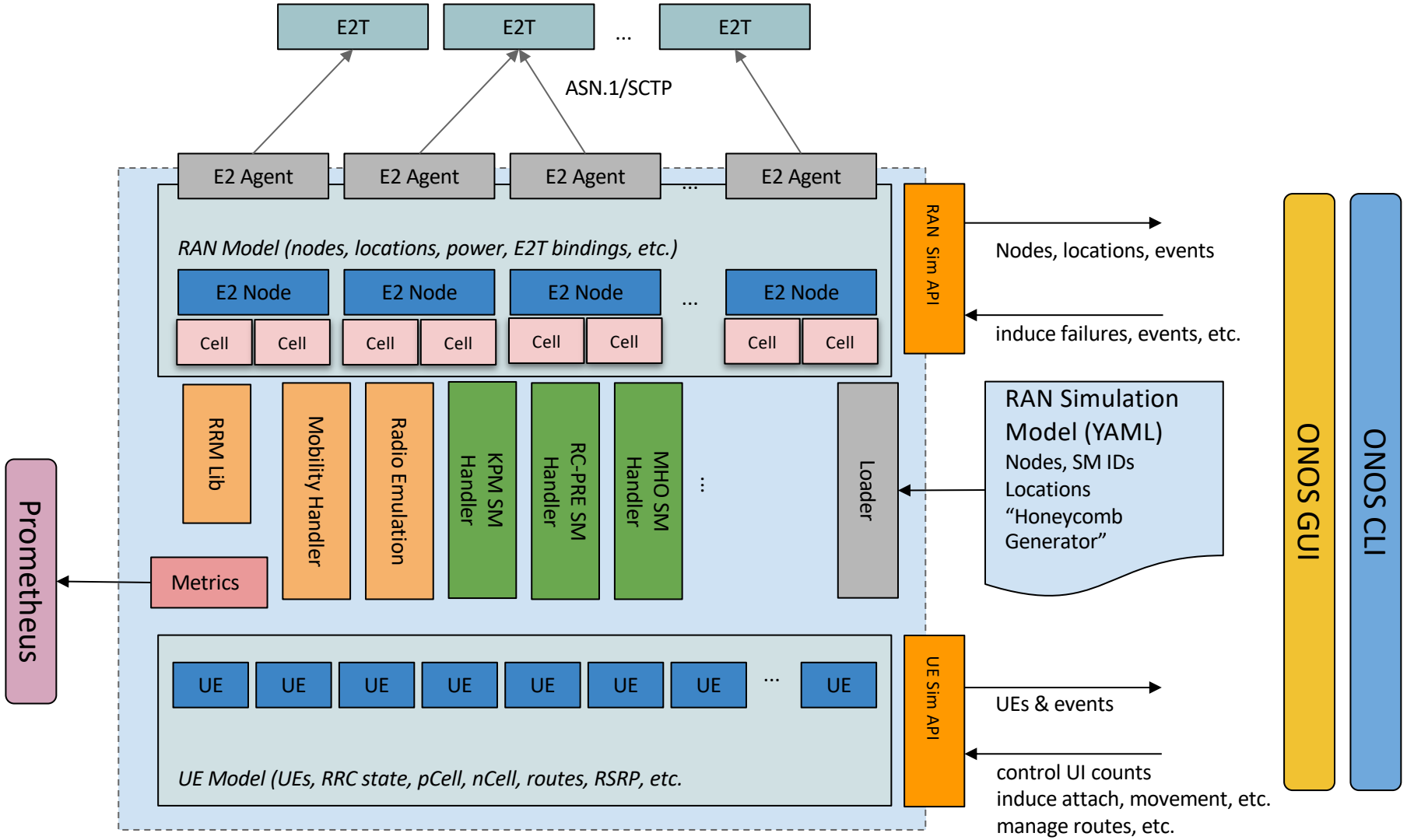
- xApp makes Handover decision - could trigger handover even without A3 event
- New Service Model developed for this use case, to enable RIC to get individual UE information (RSRP, RRC status etc) and send Handover decision to CU
- MHO test application subscribes to MHO SM; stores individual UE information in UE-NIB that other xApps can leverage
- WIP with Intel Connectivity Management xApp on python app-SDK using GNN-RL techniques
- Works with RANSim in “MHO” mode
- Not supported yet in real CU/DU/gNB
- Part of SD-RAN 1.3 release

RAN Simulator

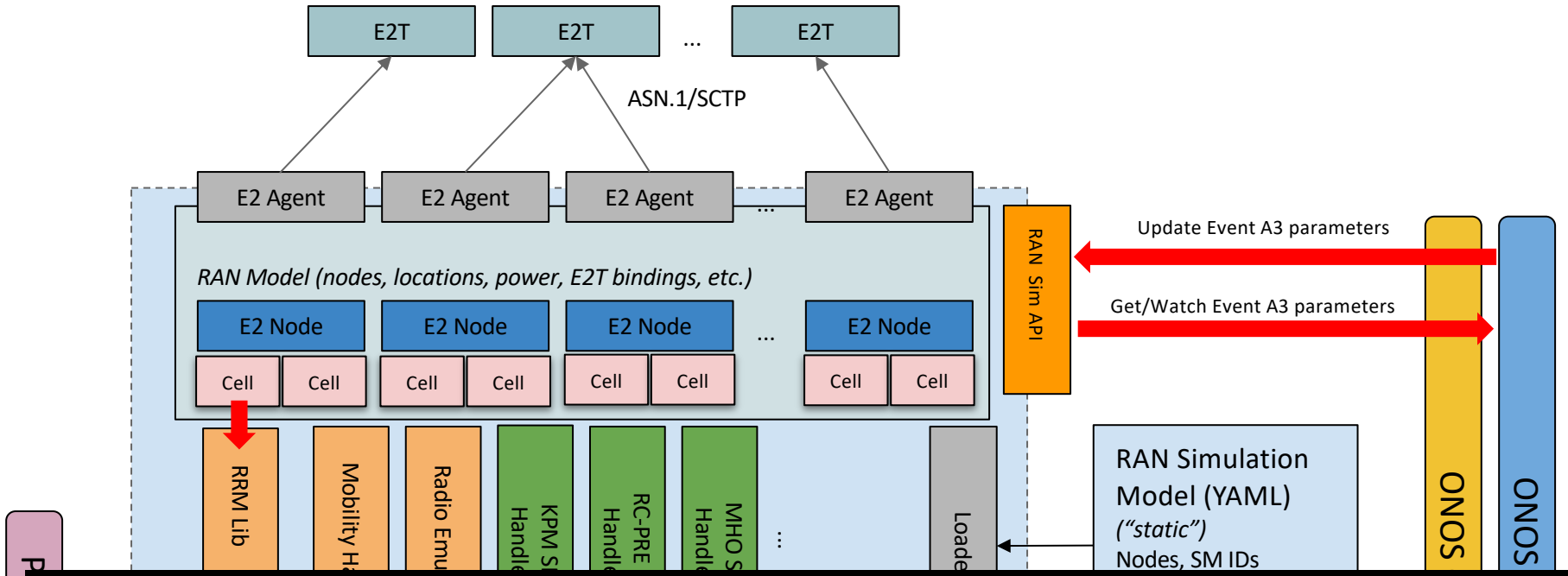
SD-RAN Project



RAN-Simulator Architecture



RAN-Simulator Model and API for Mobile Handover

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onos-cli-594848b59d-k5qsp:~$ onos ransim get cells
ECGI              #UEs Max UEs    TxDB       Lat       Lng Azimuth     Arc   A3Offset     TTT  A3Hyst CellOffset FreqOffset Color    Neighbors
343332707639810      0    99999    0.00    52.503    13.454     120     120          5       5       5          5          5 green    343332707639809,343332707639811,343332707639554
343332707639809      0    99999    0.00    52.503    13.454       0     120          4       4       4          4          4 green    343332707639553,343332707639810,343332707639811
343332707639553      0    99999    0.00    52.485    13.405       0     120          1       1       1          1          1 green    343332707639555,343332707639809,343332707639554
343332707639554      0    99999    0.00    52.485    13.405     120     120          2       2       2          2          2 green    343332707639553,343332707639555,343332707639810
343332707639555      0    99999    0.00    52.485    13.405     240     120          3       3       3          3          3 green    343332707639811,343332707639553,343332707639554
343332707639811      0    99999    0.00    52.503    13.454     240     120          6       6       6          6          6 green    343332707639555,343332707639809,343332707639810

onos-cli-594848b59d-k5qsp:~$ onos ransim set cell 343332707639554 --a3-offset 10 --a3-ttt 1024 --a3-hyst 1000 --a3-celloffset 1000 --a3-freqoffset 2000
Cell 343332707639554 updated

onos-cli-594848b59d-k5qsp:~$ onos ransim get cells
ECGI              #UEs Max UEs    TxDB       Lat       Lng Azimuth     Arc   A3Offset     TTT  A3Hyst CellOffset FreqOffset Color    Neighbors
343332707639810      0    99999    0.00    52.503    13.454     120     120          5       5       5          5          5 green    343332707639809,343332707639811,343332707639554
343332707639809      0    99999    0.00    52.503    13.454       0     120          4       4       4          4          4 green    343332707639553,343332707639810,343332707639811
343332707639553      0    99999    0.00    52.485    13.405       0     120          1       1       1          1          1 green    343332707639555,343332707639809,343332707639554
343332707639554      0    99999    0.00    52.485    13.405     120     120         10    1024    1000       1000       2000 green    343332707639553,343332707639555,343332707639810
343332707639555      0    99999    0.00    52.485    13.405     240     120          3       3       3          3          3 green    343332707639811,343332707639553,343332707639554
343332707639811      0    99999    0.00    52.503    13.454     240     120          6       6       6          6          6 green    343332707639555,343332707639809,343332707639810
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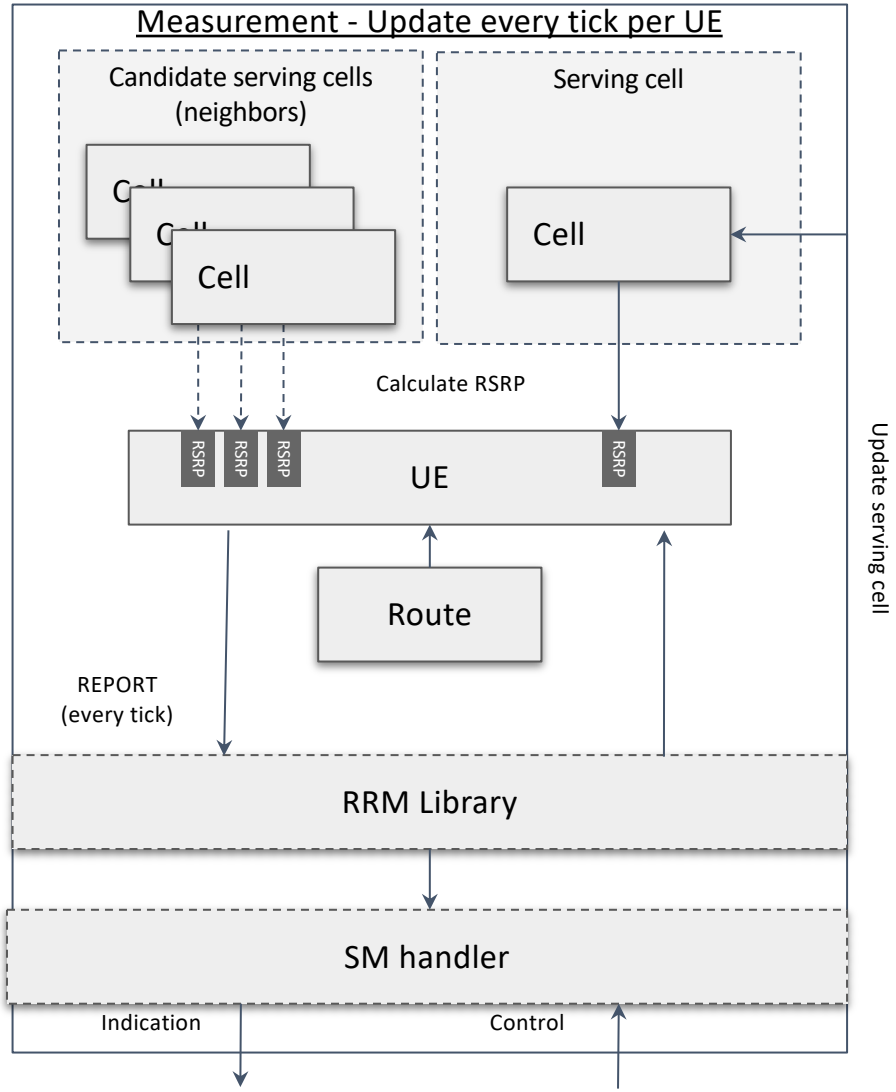
Measurement and A3 Handover in RAN-Simulator



Measurement - every tick, per UE

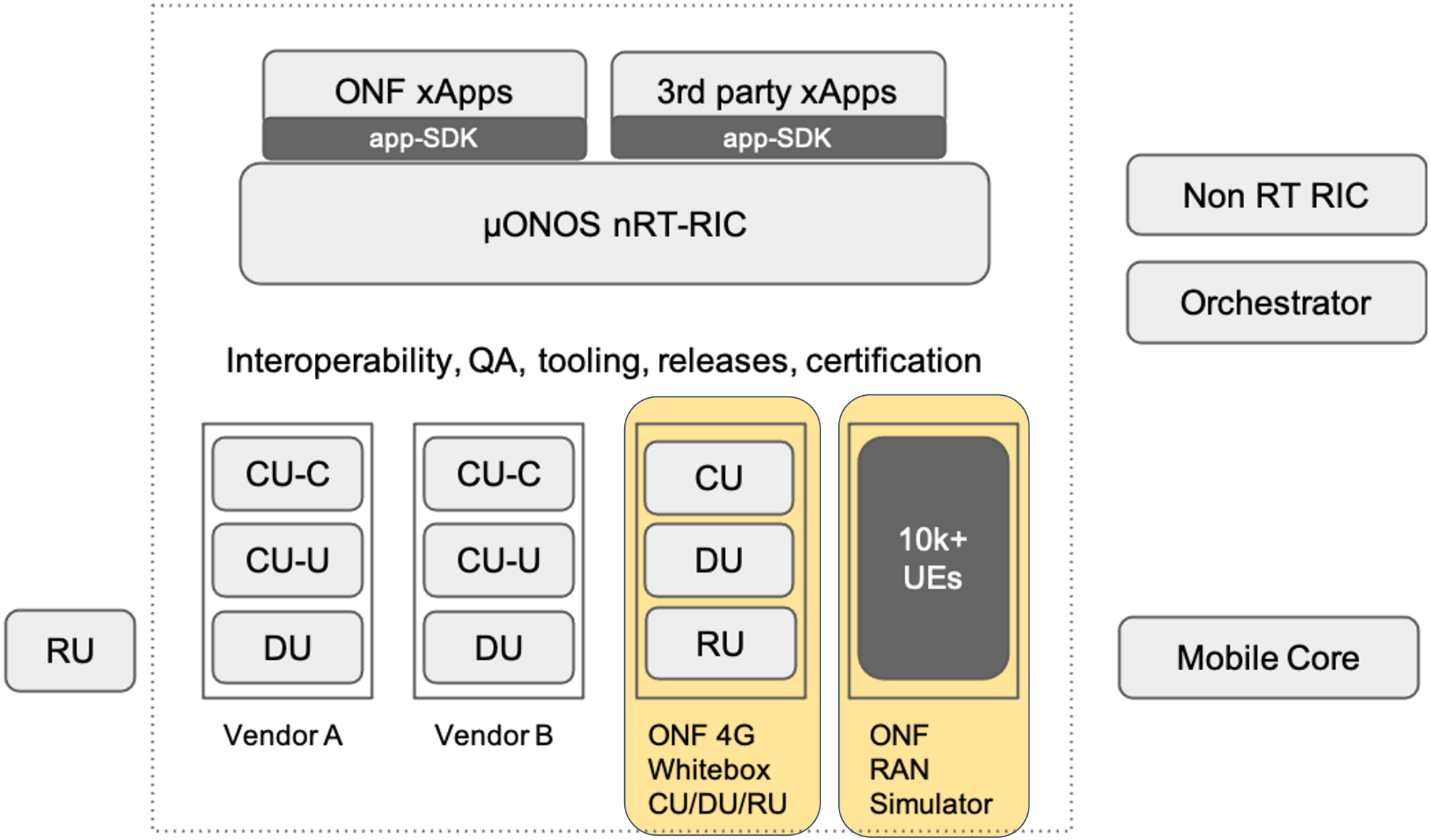
- *UE*: calculating RSRP every tick
  - Moving on a path every tick
  - Changing location → changing received signal strength
  - ⇒ Updating RSRP of serving/neighbor cells every tick
- RSRP calculation based on
  - Directional antenna model
  - Free space path-loss model

A3 Handover - per UE

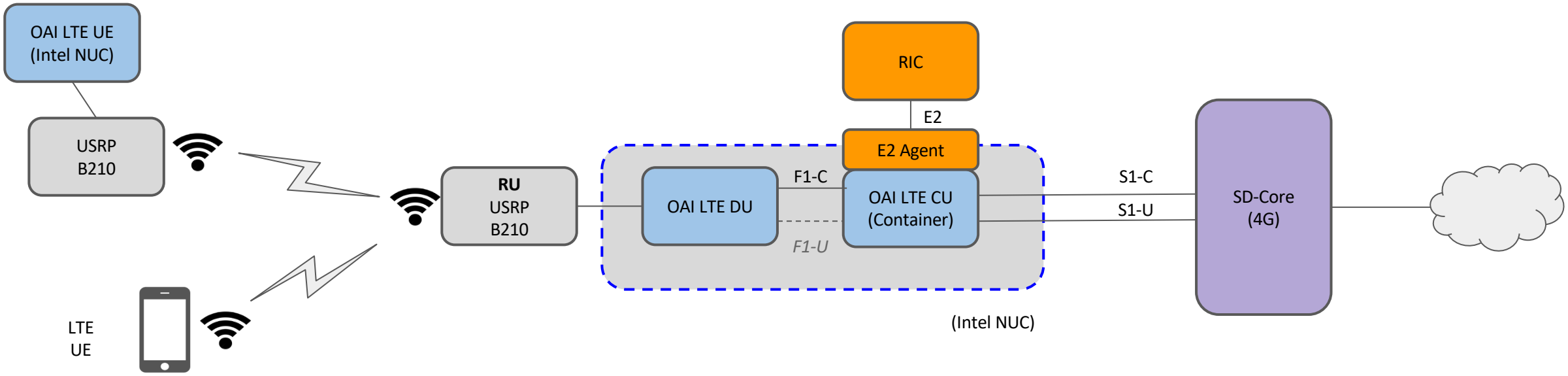
- Reporting measurement to "*RRM Library*" every tick
- If A3 handover event is generated, then SM handler is informed
- Depending on SM, A3 event parameters can be influenced

Whitebox Support

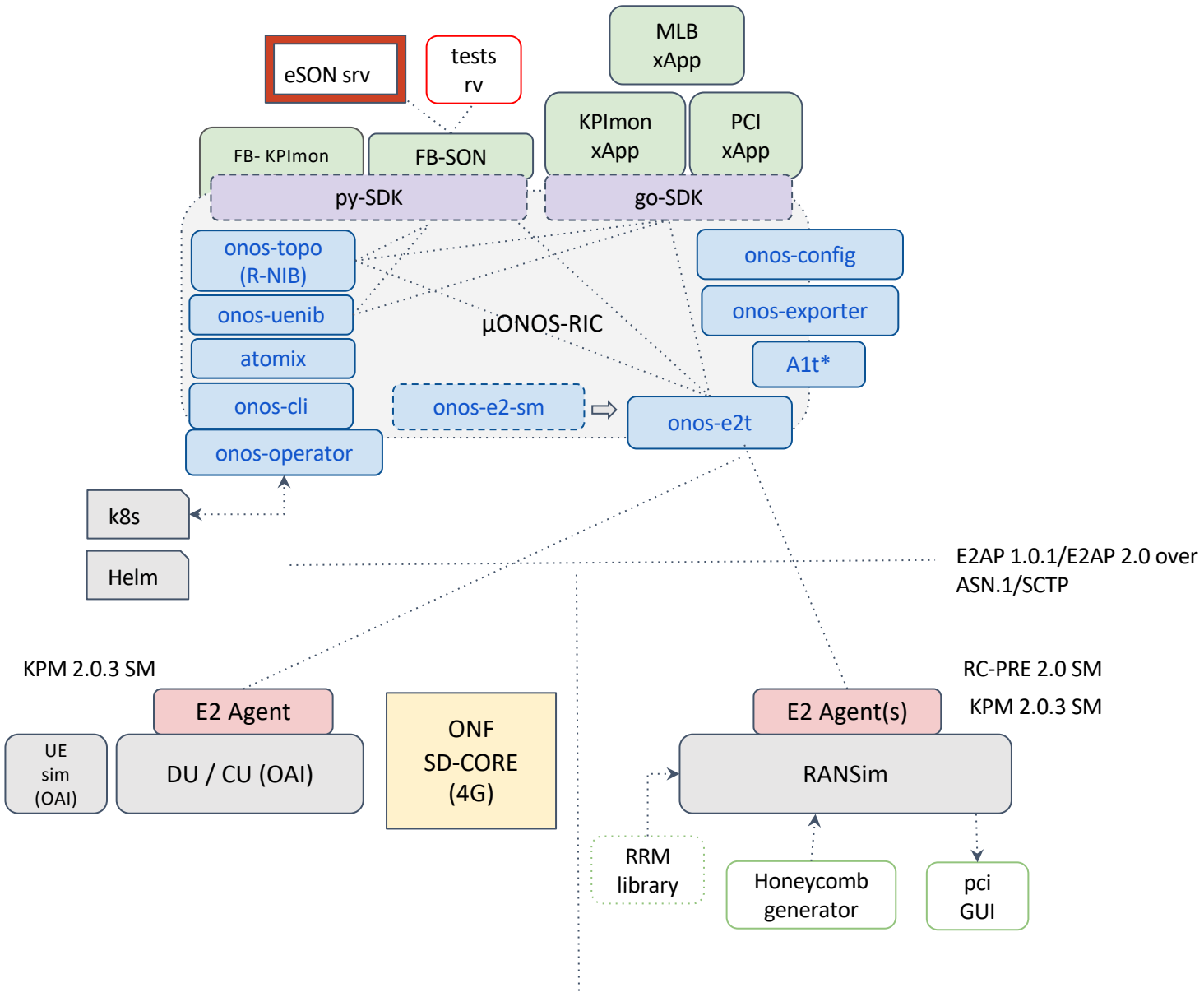
SD-RAN Project



SD-RAN Whitebox LTE - CU/DU/RU & UE



sdRan-in-a-Box (RiaB)



SD-RAN Trial

Commencing the Berlin SD-RAN Field Trial

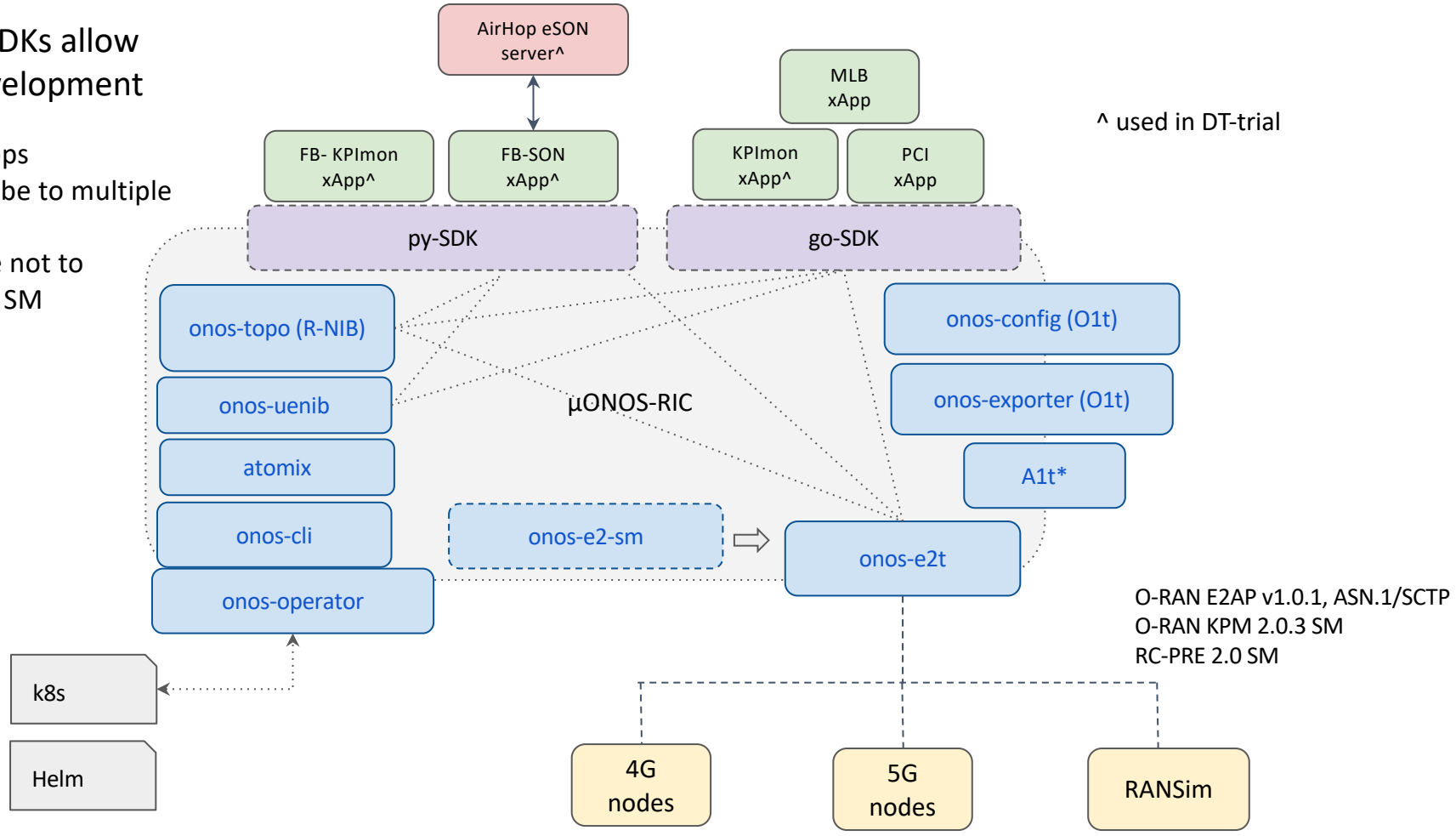
- Outdoor Trial at the Deutsche Telekom Digital Innovation Arena in Berlin
- ONF's O-RAN compliant open-source near-Real-Time RIC and xApps enable
  - KPI: mobile telemetry
  - PCI: physical cell conflicts resolution
  - MLB: mobility load balancing
- Edge cloud connected to 4G and 5G small cells disaggregated into RU-DU and CU, conform to O-RAN fronthaul and midhaul interfaces
- ONF's SD-Core and SD-Fabric projects provide disaggregated 4G and 5G control and user planes
- Hybrid cloud enabling mobile network (fully containerized) managed and controlled by ONF's Aether platform

SD-RAN's µONOS-based nRT-RIC

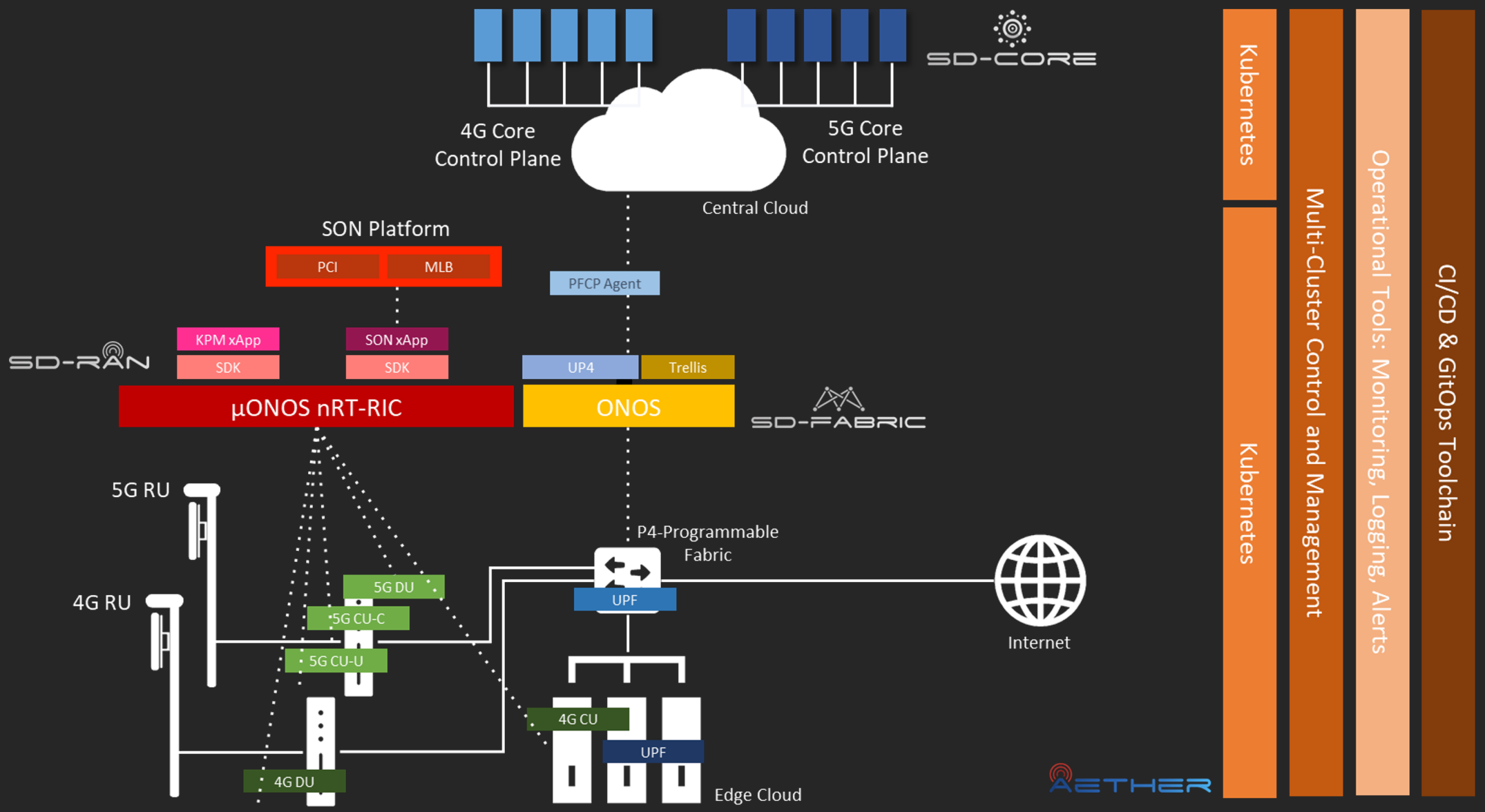
cloud-native microservices architecture

RIC platform & app-SDKs allow flexibility in xApp development

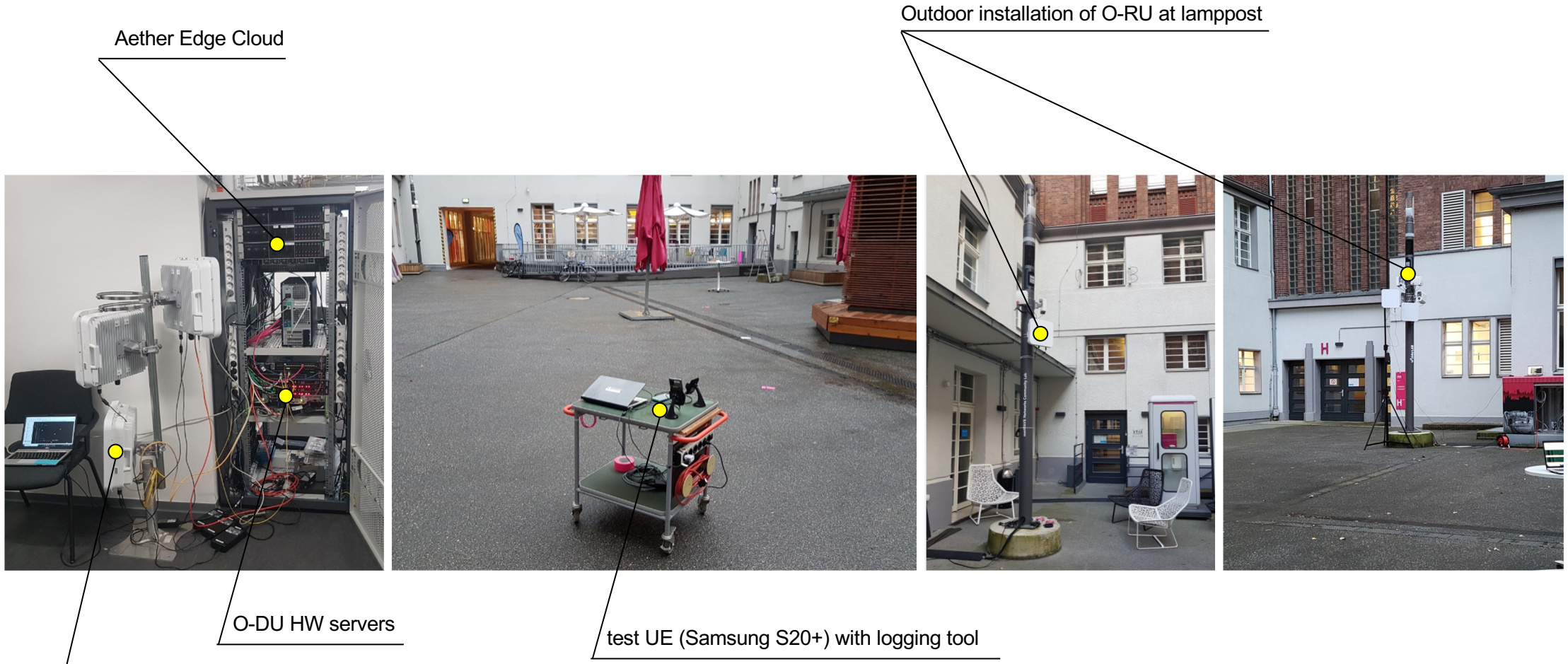
- Multiple KPM apps
- Apps can subscribe to multiple SMs
- Apps can choose not to subscribe to any SM



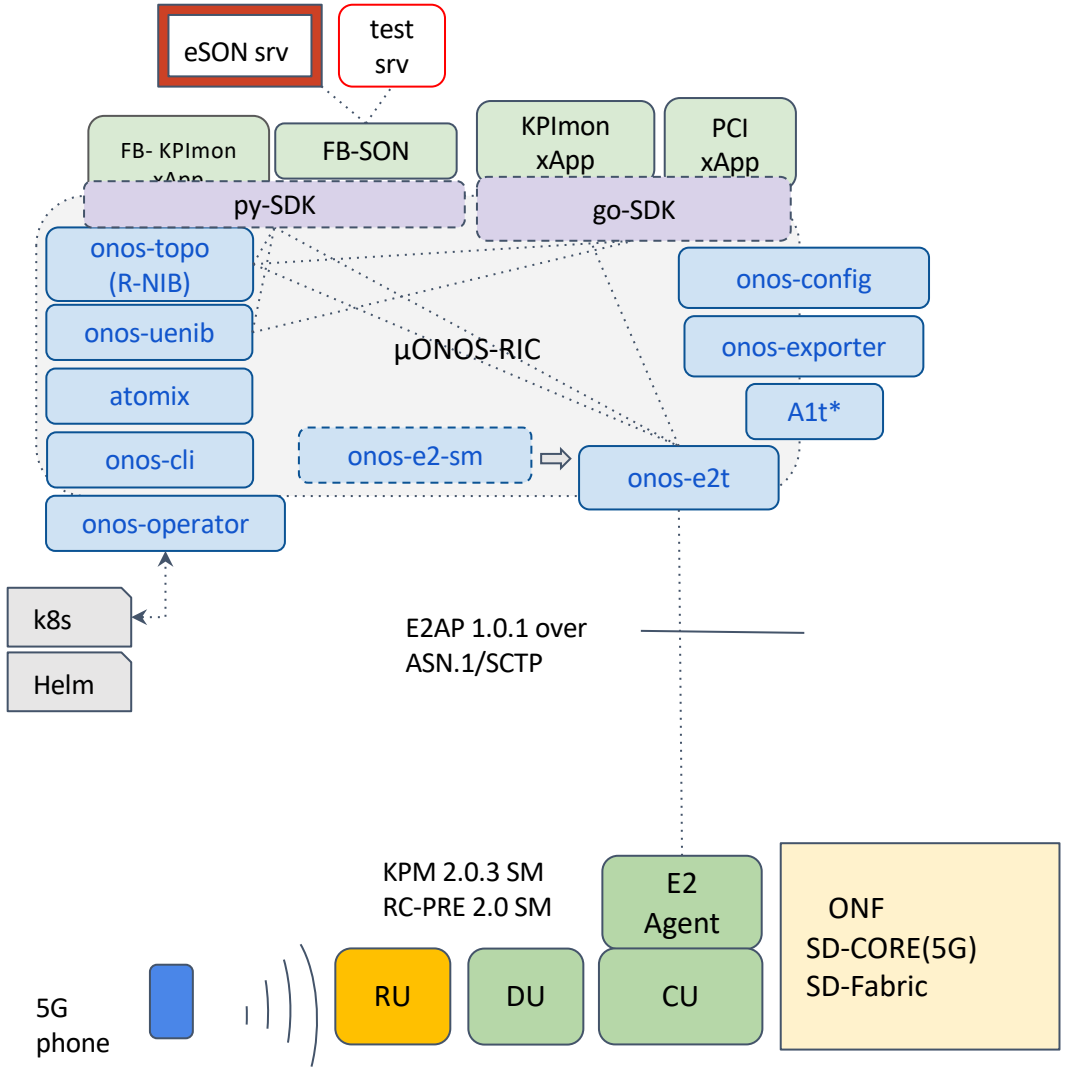
Berlin SD-RAN Outdoor Field Trial



Berlin SD-RAN Setup



SD-RAN Commercial 5G RU/DU/CU Integration



Foxconn, Intel, Radisys

Integration Labs

- ONF, Menlo Park
  - Radisys containerized CU, DU and UEsim + ONF RIC + ONF test-xApps + ONF 5G SD-Core
- Radisys, Bangalore
  - Radisys containerized CU, DU and UEsim + ONF RIC + ONF test-xApps + Radisys 5G core
- Facebook, Menlo Park
  - Foxconn indoor RUs, Radisys/Intel DU server (1st gen) + ONF RIC + FB xApps + AirHop's eSON server + ONF/Radisys 5G core
- Deutsche Telekom, Berlin
  - Foxconn outdoor RUs, Radisys/Intel DU server (2nd gen) + ONF RIC + ONF & FB xApps + AirHop's eSON server + ONF Aether (4G & 5G SD-Core + SD-Fabric - P4-UPF & Intel BESS-UPF)

Joint O-RAN & TIP PlugFest 2021

- Demonstration and verification of multi-vendor O-RAN architecture based on ONF SD-RAN reference implementation
- 5G End-to-end Performance Measurements
- Validated KPM and PCI xApps (ONF and Facebook + AirHop)
- Validation of use cases on different setups (Facebook, Radisys, ONF Menlo)
- Mobility Load Balancing: Handover among 2 cells
  - AirHop eson server integrated with fb-ah-xapp
  - Capacity and Overload Threshold per NRCGI
  - RC-PRE Service Model
  - Control offset value (ocn_rc) of neighbor cell
- O-RAN
  - O-RAN E2AP v1.0.1
  - O-RAN KPM 2.0.3 SM
  - RC-PRE 2.0 SM
- Challenges
  - Bring the infrastructure up from scratch
  - Sync/Work remotely in different time zones
  - Manual Test and Debug of SW and HW

Community

- Community calls are every 1st & 3rd Thursdays in a month and open to everyone
  - To get calendar invite, subscribe to the sdran-dev mailing list
  - **Watch previous calls: SD-RAN YouTube channel**
  - Presentation slides from previous calls: google-drive link
- Resources
  - Wiki - https://wiki.opennetworking.org/display/COM/SD-RAN
  - Code - https://github.com/onosproject
  - Docs - https://docs.sd-ran.org/master/index.html
- Preferred means of communication
  - sdran-dev slack channel (open to everyone)
  - sdran-dev mailing list (open to everyone)

Thanks!

Questions?