

A close-up, low-angle shot of a golden wheat field. The wheat stalks are in sharp focus in the foreground, with a soft, warm glow from the sun in the background, creating a bokeh effect. The overall color palette is warm, dominated by yellows, oranges, and browns.

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RAN Simulation for ONAP / SMO Use Cases

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@twitterhandle

Outline

- Introduction
- RAN Simulation for ONAP/SMO use cases
- ONAP Use Cases
- ONAP and OSC RAN Simulators
- Cellular radio simulation (ns3)
- Future work
- Discussion

RAN Simulation for end-to-end use cases

- Perspective: ONAP/OSC end-to-end use cases involving ONAP and SMO components
- Simulation of RAN includes:
 - Support for SMO to RAN Interfaces
 - Abstraction of RAN components/functionality as per use case
- Natural to have different types of RAN Simulators
- Overall objectives for ONAP/OSC community:
 - Reusable solutions - efficiency and ease of future integration
 - Avoid duplication and divergence

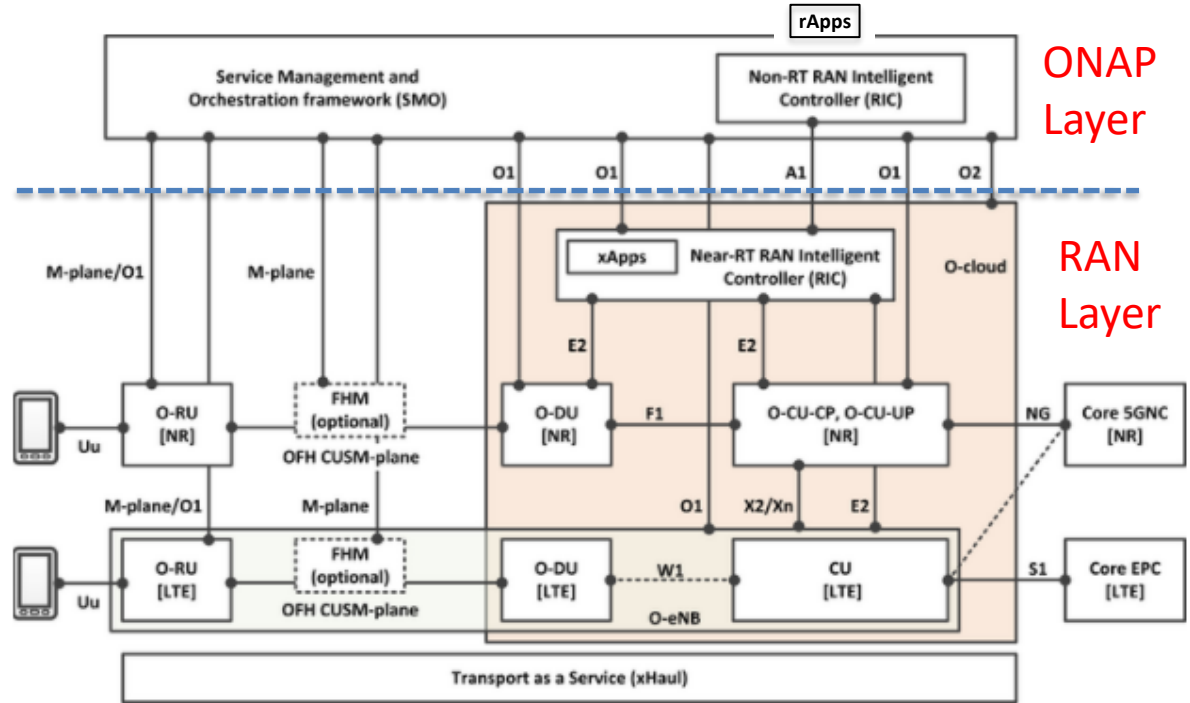
RAN Simulation: Use Case viewpoint

Use Case functions implemented:

- ONAP Layer / SMO
- Models, microservices, applications, data handling, control loops, policy

RAN functions simulated:

- **Interfaces** to/from SMO
- **Functional** logic and data flow in RAN components
- **Cellular** radio network performance



O-RAN PLUGFEST 2020 INTEGRATION AND TESTING CONFIGURATION

RAN Simulation areas

Interface simulation

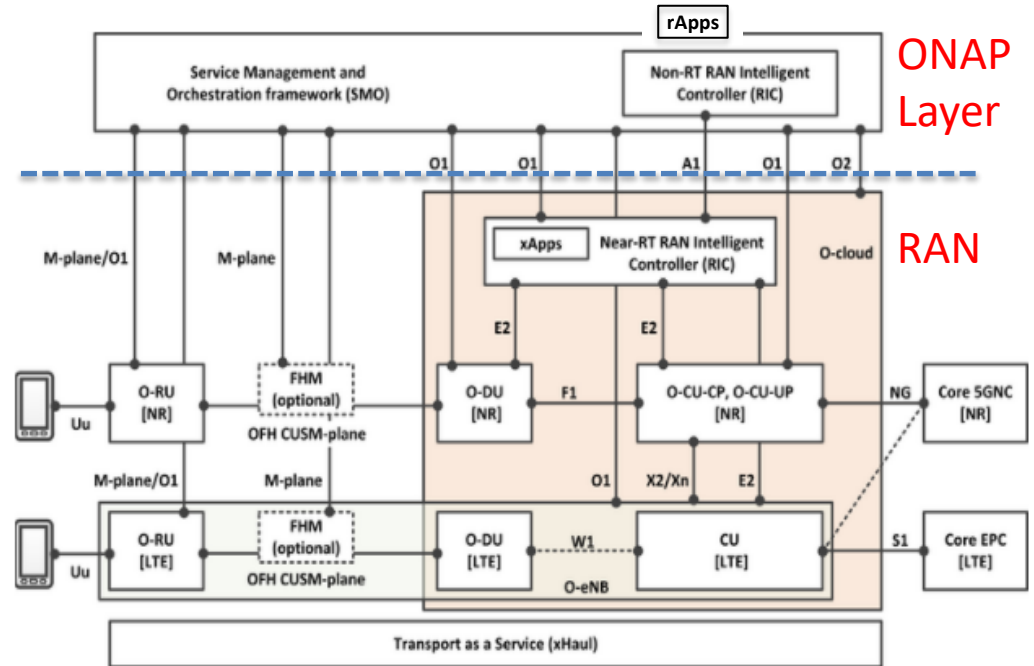
- Focus on O-RAN interface
- e.g., O1 netconf server, VES client
- Configuration of RAN (O1, M-plane)
- Data from network (O1, M-plane)
- Guidance to xApps (A1)
- Cloud config/data (O2)

Functional simulation

- Logic, data flow for Use Case
- xApp/E2 processing
- CU/DU/RU function

Cellular network simulation

- Radio channel conditions, UE mobility, user plane performance (throughput, latency, loss)



O-RAN PLUGFEST 2020 INTEGRATION AND TESTING CONFIGURATION

Test-Stubs / Simulators / Emulators

Pointers to definitive descriptions would be very welcome!

- Test-Stub
 - Very basic small skeletal placeholder, (usually) stateless, with (usually) hardcoded responses to a very small subset of possible inputs/contexts.
 - Often used to verify connectivity, non-functional aspects, aid test coverage, or as an “early-stage simulator”
- Simulator
 - Mimics a subset of behavior of a simulated function/interface/system with correct data/information models
 - Behaves or operates like “the real thing” when provided with a set of controlled inputs
 - Realism/Fidelity is a key differentiator!
- Emulator
 - Indistinguishable / exactly like “the real thing” for a wide range of usage scenarios
 - Often used for validation/testing late in the development process
- Simulator/Emulators can only be an approximation of “The Real Thing”
 - Usefulness of a simulator is entirely subjective – depending on the consumer’s custom usecase/requirements
 - Best ones are customizable/extensible/configurable/model-driven
 - Trade-off: advantages vs realism/fidelity
- Advantages of Simulator/Emulator
 - More convenient, accessible, extensible, repeatable, cheaper, safer, timely, more/less/appropriately realistic

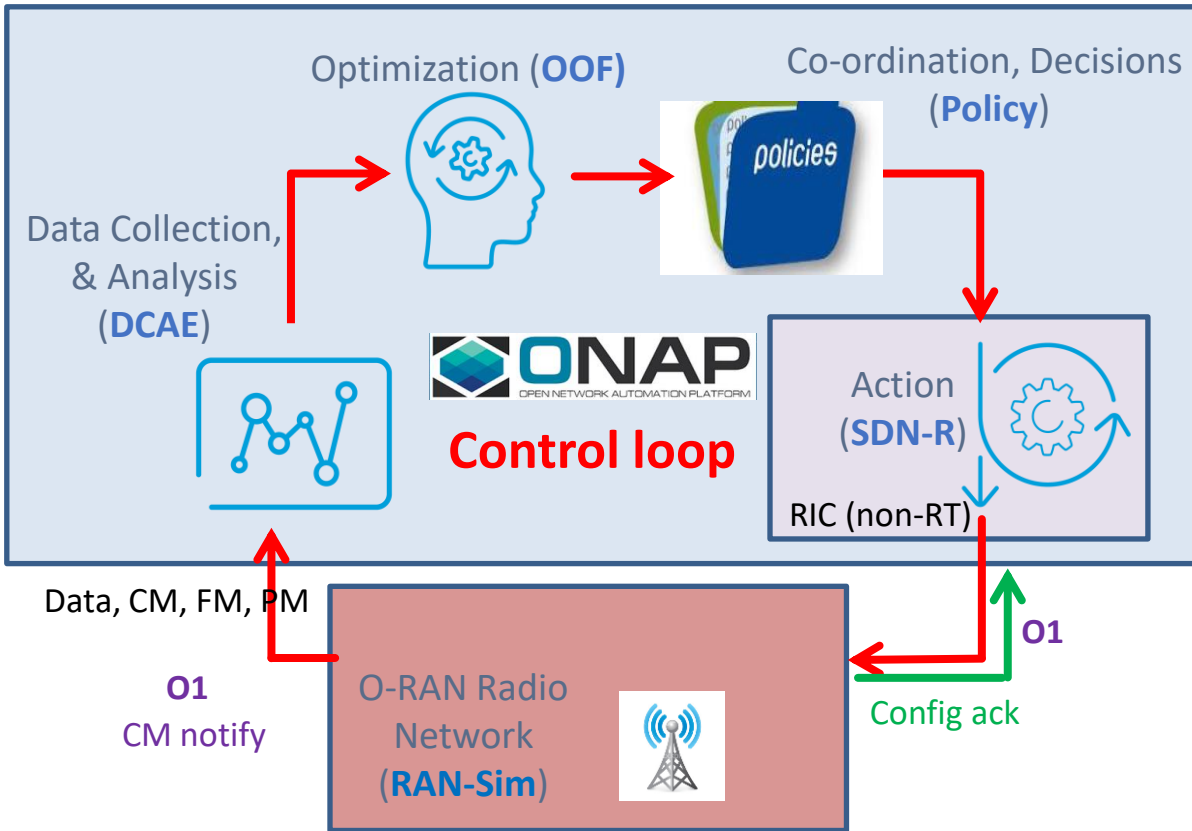


ONAP Use Cases

(using ONAP RAN-Sim Simulator):

- ONAP SON Use Case
- ONAP Slicing Use Case

ONAP SON Use Case: Rel 3 to Rel 9



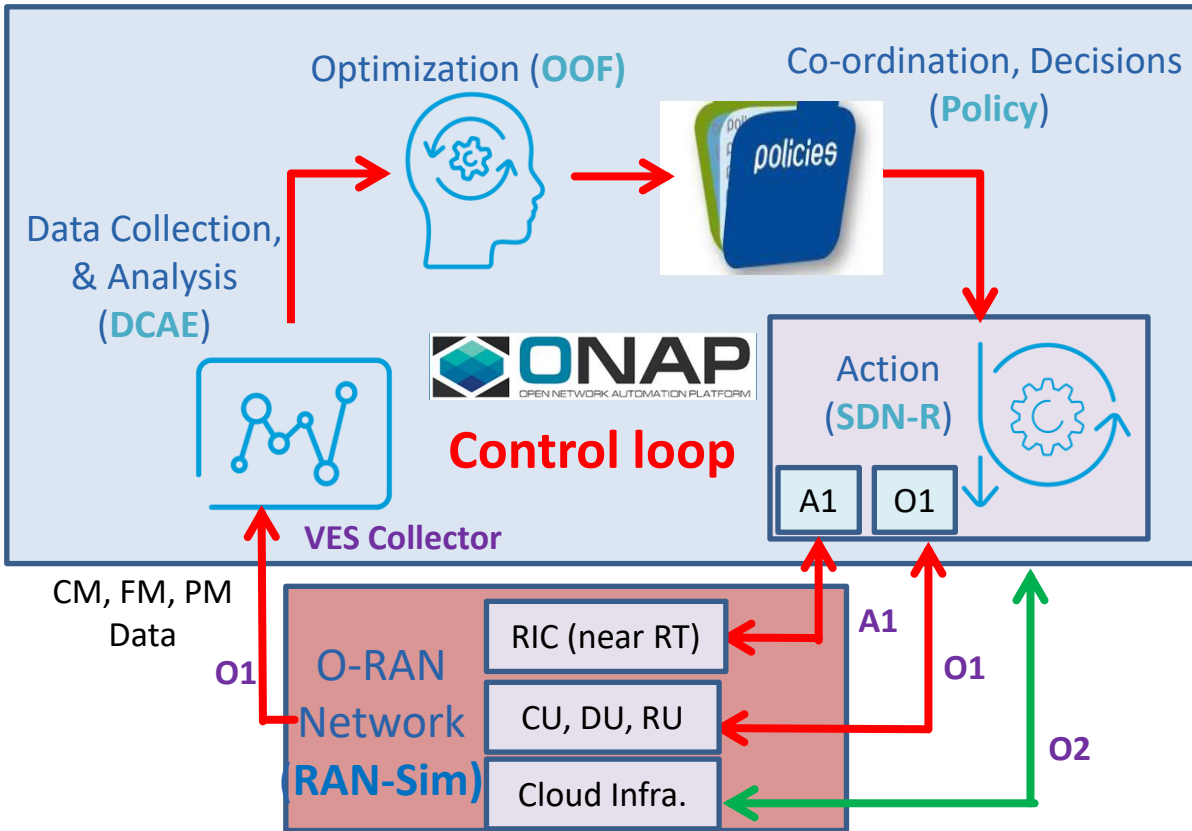
- SON \Leftrightarrow Control Loop (CL)
- Companies can use framework to add proprietary SON solutions, including optimization algorithms, etc.

- OOF-SON use case has built a foundation for ONAP/O-RAN integration
- Radio network uses common netconf/yang model

Data flows

- SDN-R to RAN: netconf-based configuration
- RAN to DCAE: VES format for FM alarms, PM KPI, CM Notification

ONAP SON Use Case – Release 10+



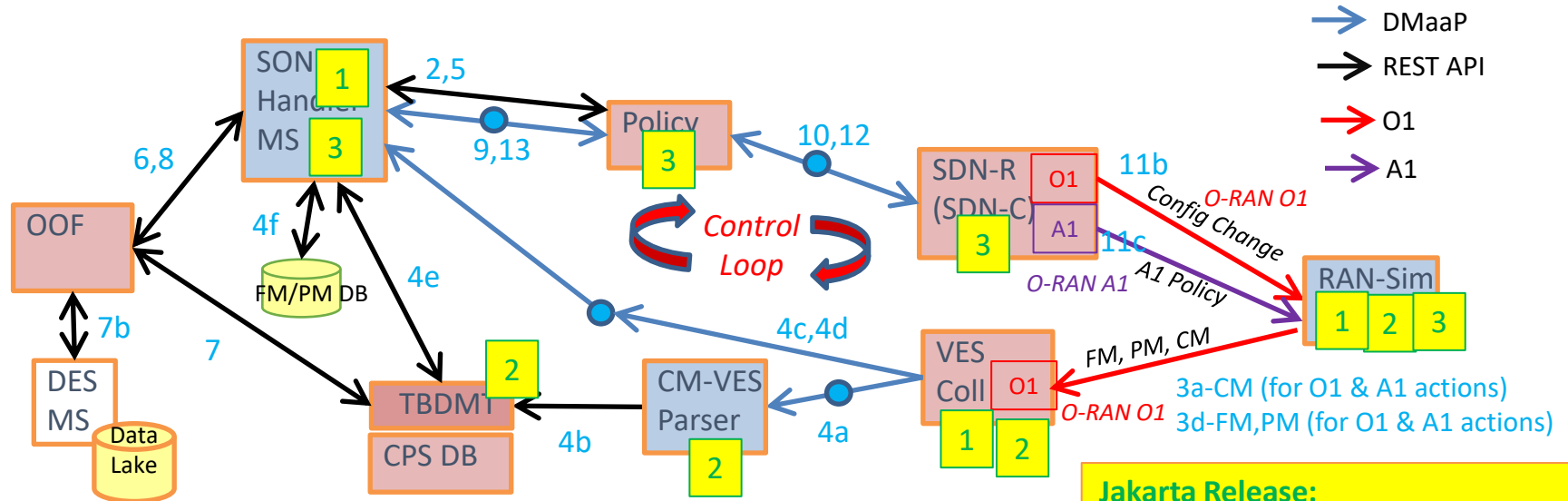
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Data flows

- SDN-R to RAN: (O1) netconf-based configuration, (A1) Policy/guidance to xApp in Near-RT RIC
- RAN to DCAE: (O1) VES format for FM alarms, PM KPI, CM Notification

ONAP SON Use Case – Control Loop with O1 & A1 (Rel 10/11)

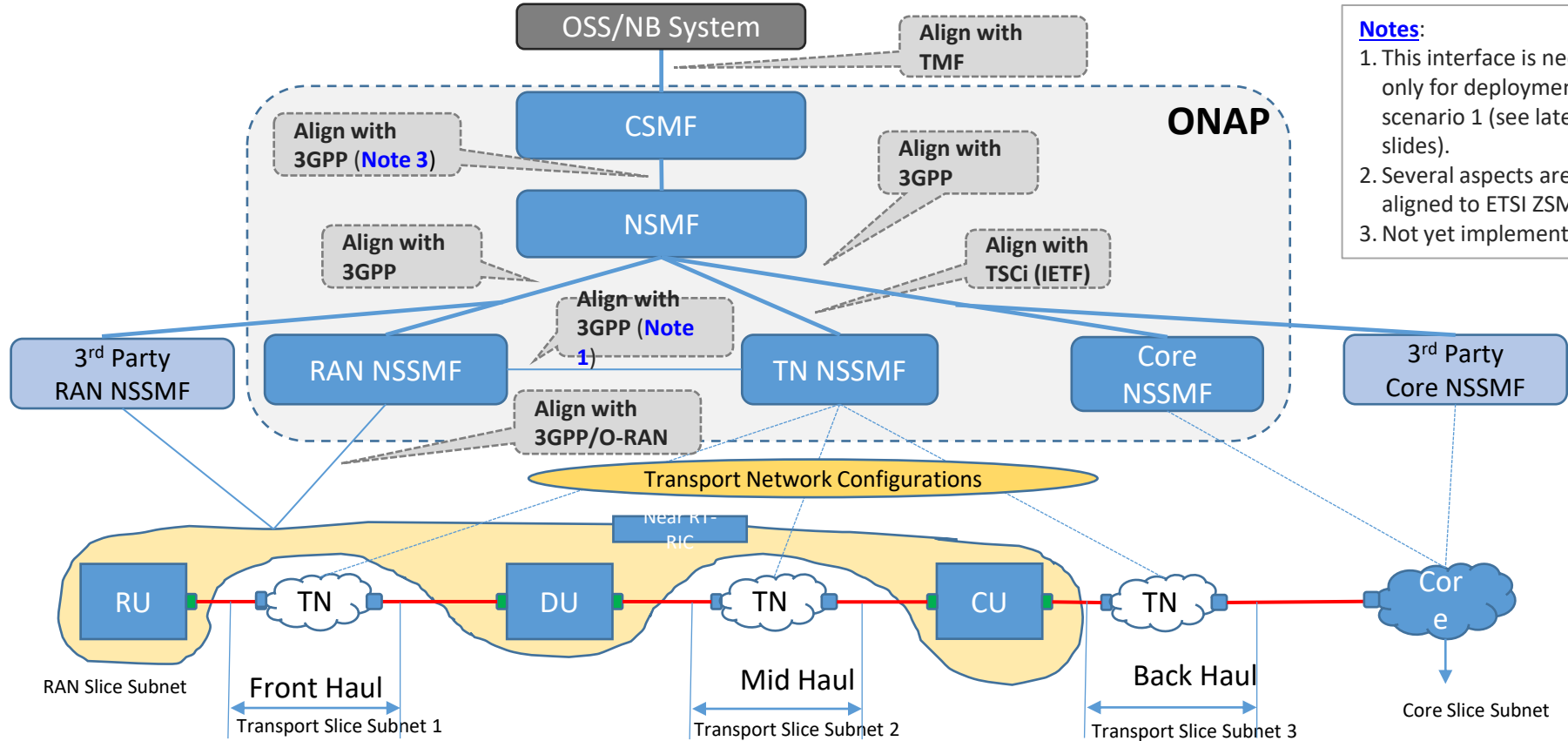


- Steps 3a,4a,4b,4c: CM data received from RAN, update of state in CPS DB
- Steps 3d,4d: FM/PM data received from RAN, processing in SON MS
- Steps 2,4e,4f, 5: SON MS analyzes need for optimization
- Steps 6,7,7b,8: Optimization using OOF
- Steps 9,10,11b,11c: Automated action to make change in RAN (O1 and A1)
- Steps 11,12,13: Action status

Jakarta Release:

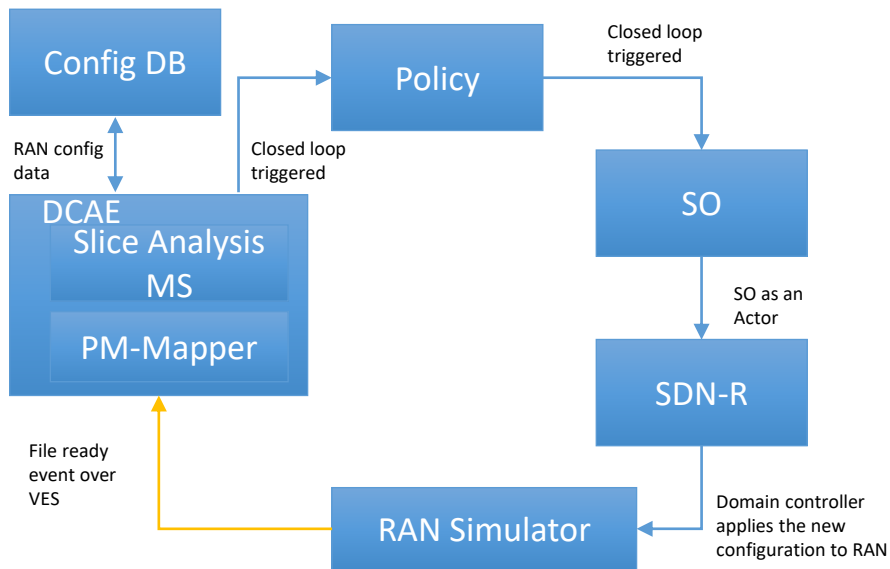
1. New VES Message format to align with O1
2. Complete CM-Notify carryover work
3. Include A1-based action (stretch goal, may be planning only)

E2E Network Slicing: Architecture & Interfaces



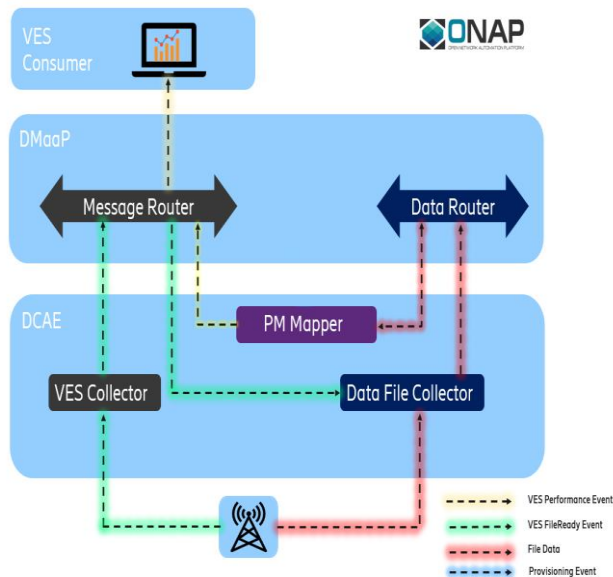
- Notes:**
1. This interface is needed only for deployment scenario 1 (see later slides).
 2. Several aspects are also aligned to ETSI ZSM.
 3. Not yet implemented

E2E Network Slicing – Closed Loop



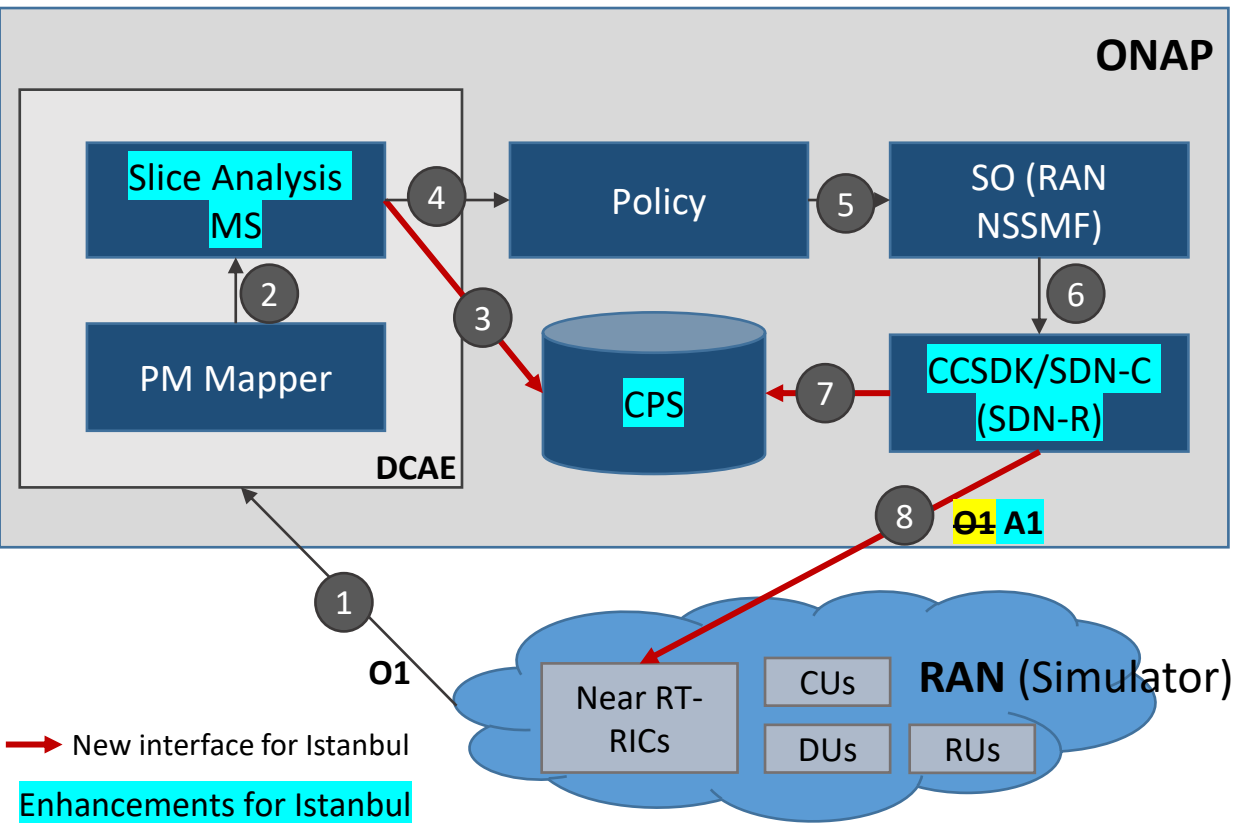
Data flow from RAN n/w to DCAE-Slice Analysis MS

MS



Ref. ONAP wiki

E2E Network Slicing Closed Loop: Istanbul Release



- The PM data collected from RAN in Step 1 is DL/UL PRB used for data traffic.
- The configuration update determined by Slice Analysis MS and triggering Policy in Step 4 is slice specific throughput guidance for Near-RT coverage area (i.e., at Near-RT RIC level).
- Step 8 is over **O1** in Honolulu, it will be over **A1** in Istanbul (using A1 adaptor). - **Deferred**

Notes:

1. DFC and VES Collector are not shown in the flow but are used.
2. Initial configuration may also be over A1 (based on Slice Profile decomposition) in the future.

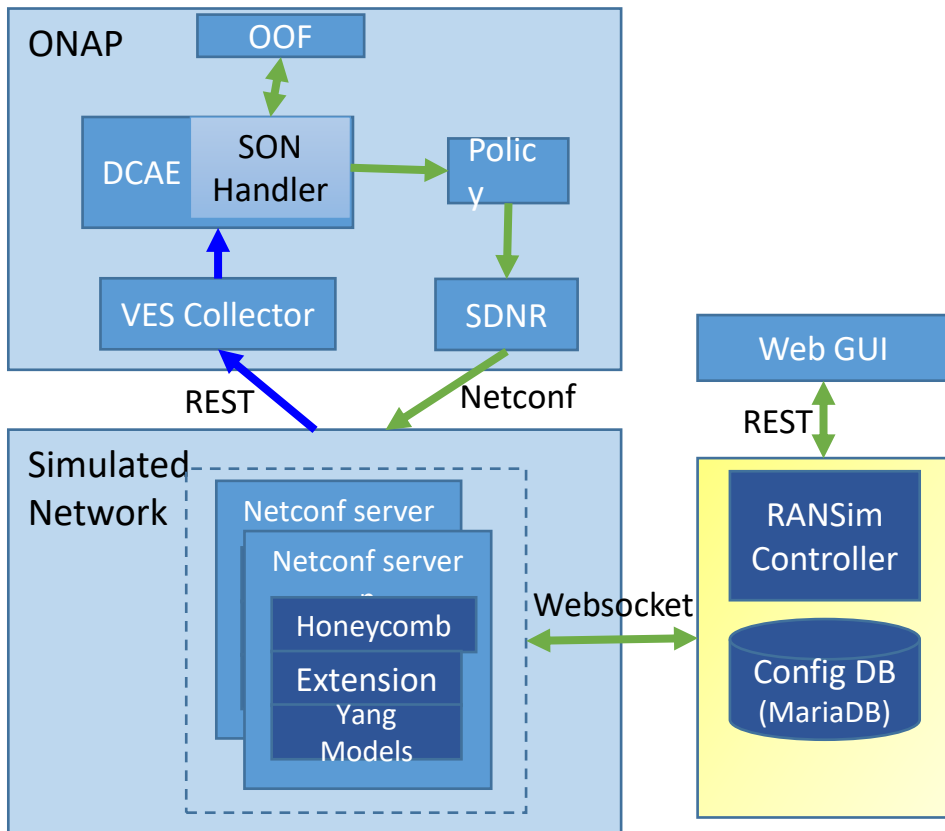


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OPEN NETWORK AUTOMATION PLATFORM

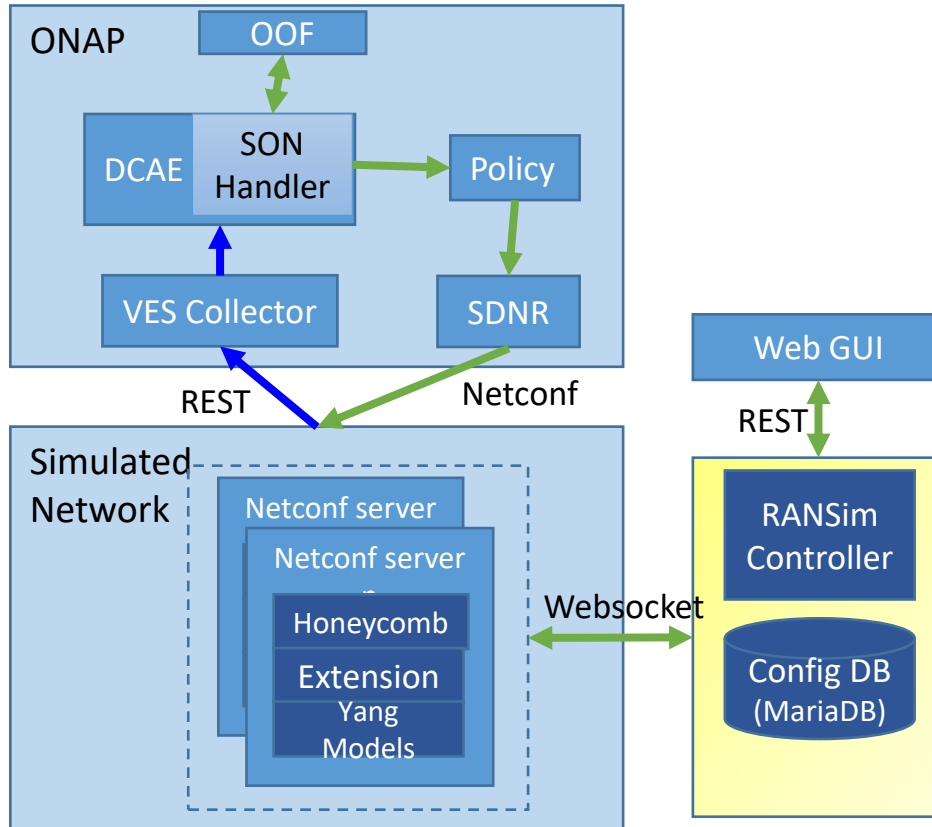
RAN-Simulator (RAN-Sim)

Approach for RAN Simulator (RANSim) – Dublin - FM



- GUI
 - Provide Control to User in UI to select a cell and modify neighbor list to simulate collision/confusion
- GUI
 - Show the modified PCI values
- Controller
 - Send message to corresponding Netconf Server about the collision/confusion
 - When the modified RAN configuration received, same is updated into DB and informed to UI
- Netconf Server
 - Send configChangeNotification to SDNR
 - **Send FM/alarm message to VES Collector for collision/confusion. Thus the control loop starts**
- Netconf Server
 - When the SDNR provides the modified RAN configuration, same is forwarded to Controller

Approach for RAN Simulator (RANSim) – Dublin - PM



- **GUI**

- Provide Control to User in UI to select a cell and generate PM data

- **Controller**

- Send PM message to corresponding Netconf Server with KPI values. Initially send good values and after few minutes send bad values for selected cell.

- **Netconf Server**

- Send PM message to VES Collector with given KPI values. Thus the control loop starts.

- **GUI**

- Show the ANR updates as dotted lines.

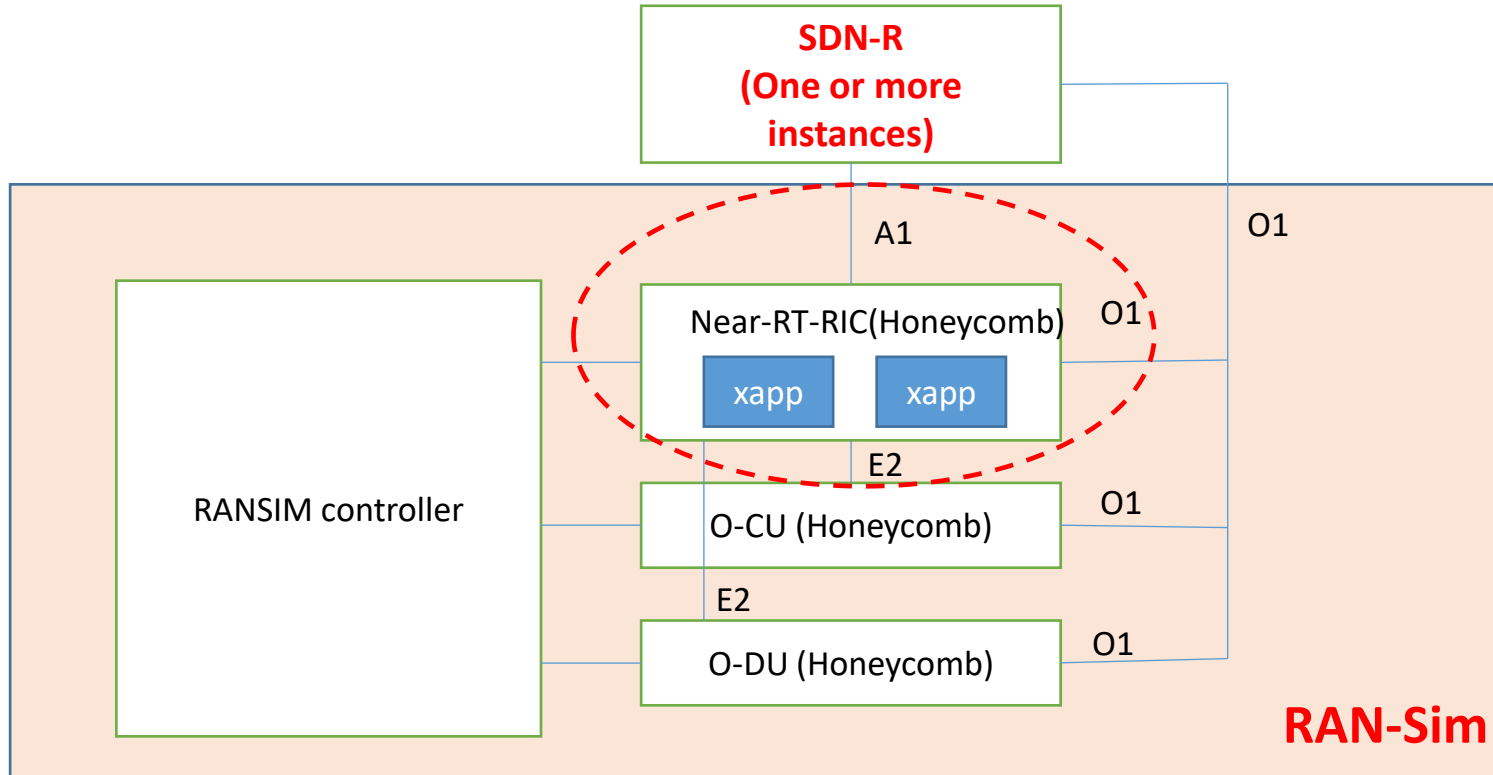
- **Controller**

- When the modified RAN configuration received, same is updated into DB and informed to UI

- **Netconf Server**

- When the SDNR provides the modified RAN configuration, same is forwarded to Controller

Enhancement to include xApp and A1



Problem: RAN-Sim Upgrade is Needed

- All SON Use Case planned work has impact on RAN-Sim
- RAN-Sim uses Honeycomb netconf server
- Honeycomb project (<https://wiki.fd.io/view/Honeycomb>) has been archived, and future support is an issue
 - There is a new project Hc2VPP (<https://wiki.fd.io/view/Hc2vpp>) which uses Honeycomb
- Other parts of RAN-Sim provide great value for ONAP and OSC Use Cases
 - Controller, Database, GUI for Usecase logic
 - VES message generation for PM, FM, CM
- Need to develop plan for:
 - Replacement of Honeycomb in RAN-Sim
 - Adding simulated Near-RT RIC and xApp in RAN-Sim for Use Cases
 - Harmonization of RAN-Sim with OSC projects (sim, o1)



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OPEN NETWORK AUTOMATION PLATFORM

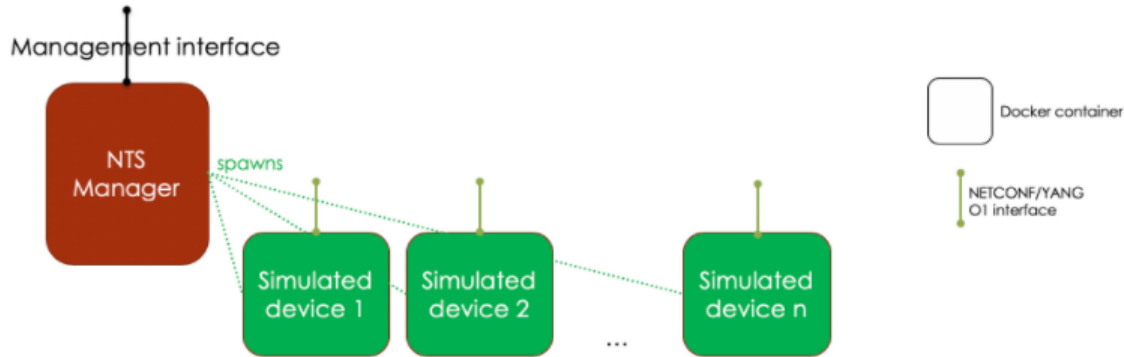
O1 simulator in OSC sim

O-RAN Software Community (OSC) sim project

Ref: <https://wiki.o-ran-sc.org/display/SIM/Architecture>

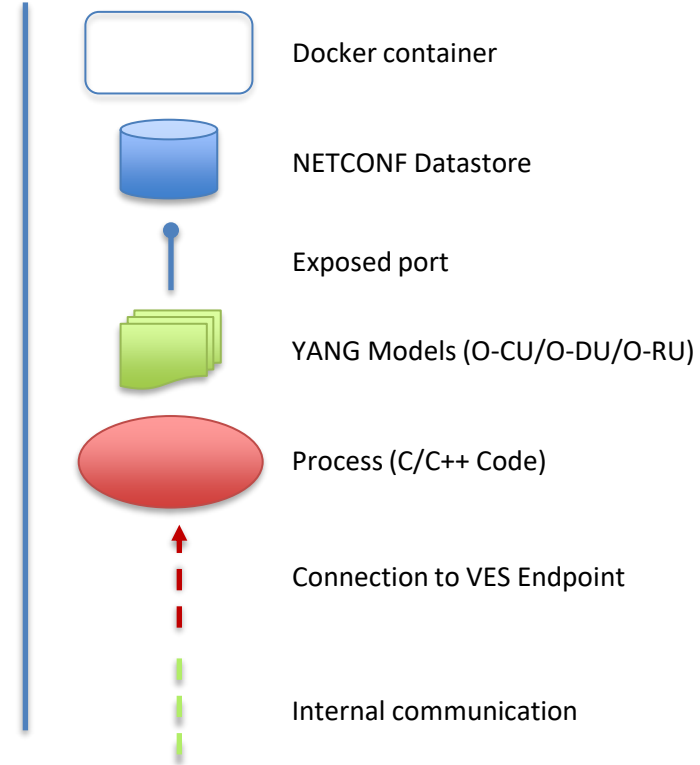
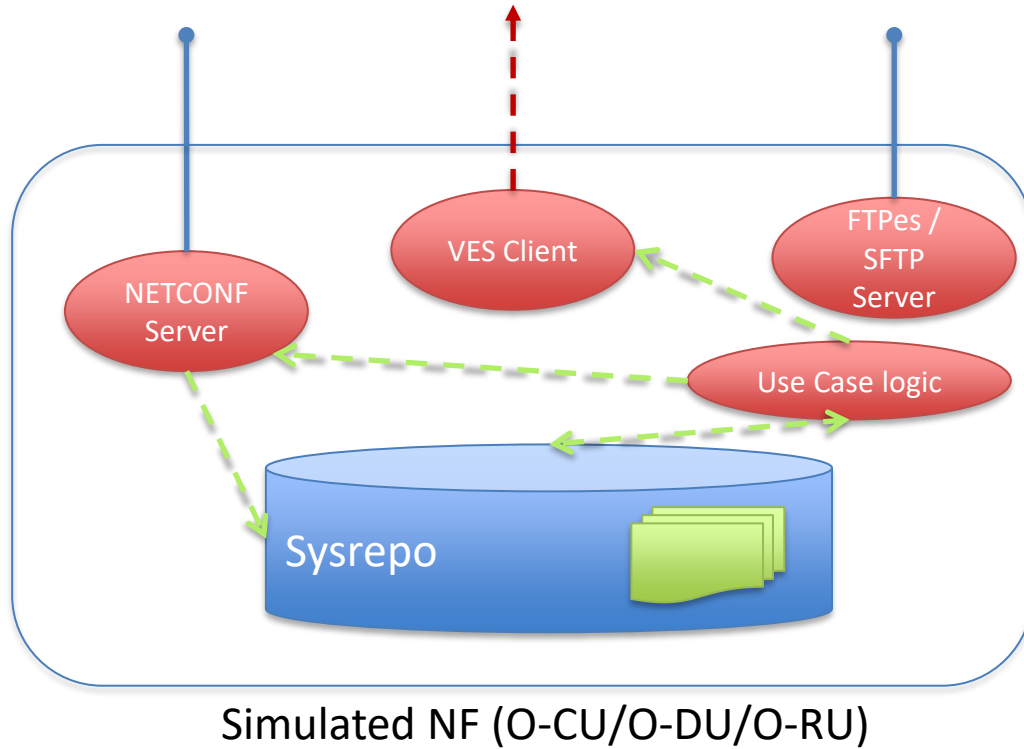
Contact: Alex Stancu

- **O1 Simulator** - its purpose is to offer simulated devices which offer the O1 NETCONF/YANG interface

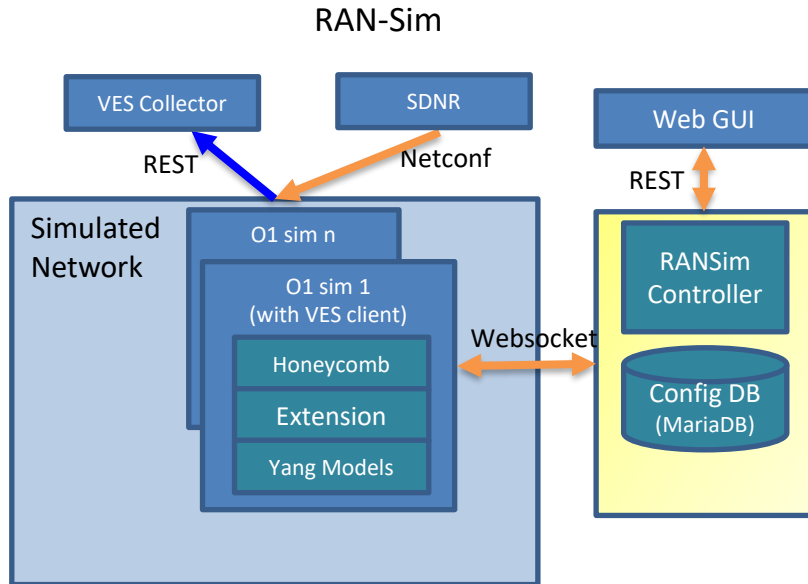


- Simulated devices in Simulated RAN are netconf (netopeer) devices representing CU/DU O1 instances with CU/DU yang models
- NTS (Network Topology Simulator) Manager uses netconf to connect to devices using yang model of simulation entities
- NTS also has NB netconf interface for external entity (e.g. SDN-R) to control simulation
- Datastore in NTS provided by netopeer

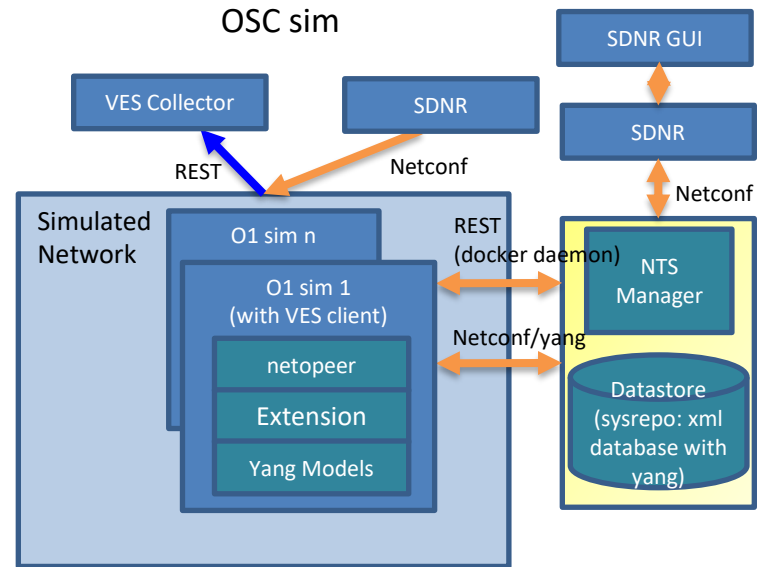
O-RAN-SC O1 Simulator architecture



Comparing RAN-Sim and OSC sim

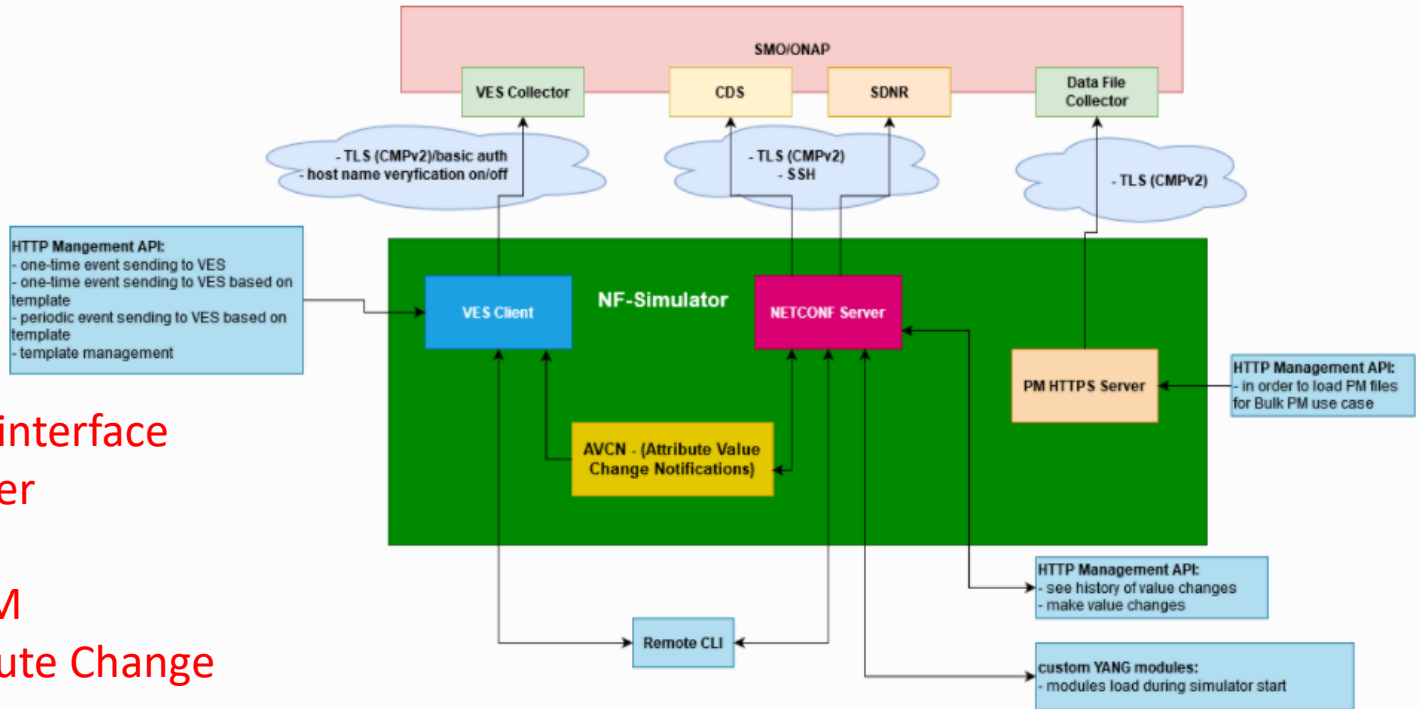


- RAN-Sim was developed for ONAP Use case
- Has use case specific logic (e.g. analyze cell relations and generate fault message)
- Netconf devices are mounted manually
- VES message details are generated in Controller as per usecase logic



- OSC sim developed as O1 building block
- NTS can be used by SDN-R to spawn O1 (CU/DU) instances. SDNR GUI can be used to configure NTS
- FM VES messages are pre-configured in O1 sim
- NTS uses netconf to each O1 sim netopeer device, and REST to the docker

ONAP NF Simulator

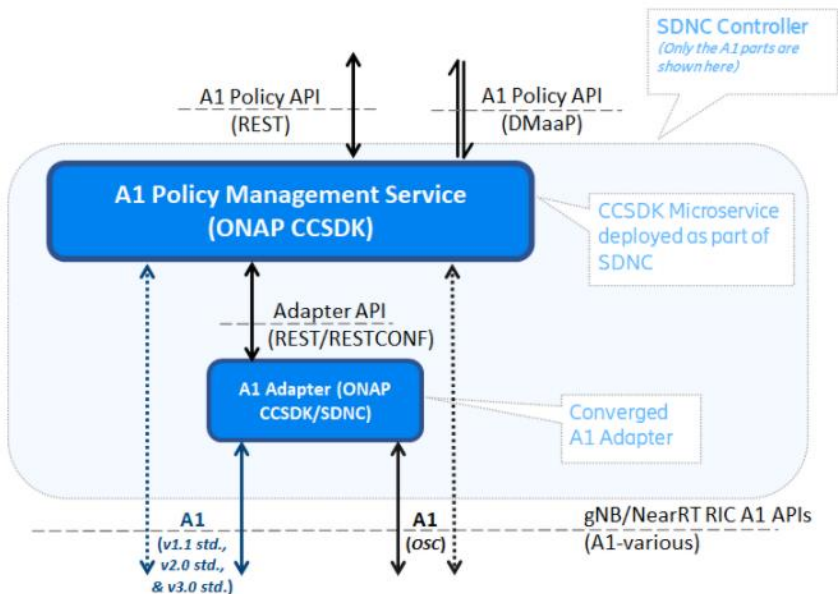


- xNF with O1 interface
- Netconf server
- VES Client
- File-based PM
- Config Attribute Change

A1 Functions in ONAP / OSC

Ref: <https://wiki.onap.org/pages/viewpage.action?pageId=84672221>

Functional view of ONAP A1 Policy functions



The figure above shows a functional view of the A1 policy functions in ONAP.

- A1-related message can be sent from Policy to SDN-R/CCSDK
- Current Control Loop architecture would use DMaaP CL message
- A1 Policy Management Service can connect to A1-termination in the Near-RT RIC with or without an A1 Adapter
- In the SON Use Case context, the A1-termination in Near-RT RIC would be part of the simulated RAN (RAN-Sim) with usecase logic in the simulated/abstracted xApp which results in events from CU/DU over O1

OSC A1 (Near-RT RIC) Simulator

Stateful A1 test stub for “South-end” of A1 Interface

- Used to create multiple stateful A1 providers (simulated near-rt-rics)
 - Supports A1-Policy and A1-EnrichmentInformation
- Does not include and app-specific behavior – just what is defined in A1 Application Protocol specs
- Implemented as a lightweight Python application
- Swagger-based northbound interface, so easy to change the A1 profile exposed (e.g. A1 version, A1 Policy Types, A1-E1 consumers, etc)
 - All A1-AP versions supported as configurable profiles

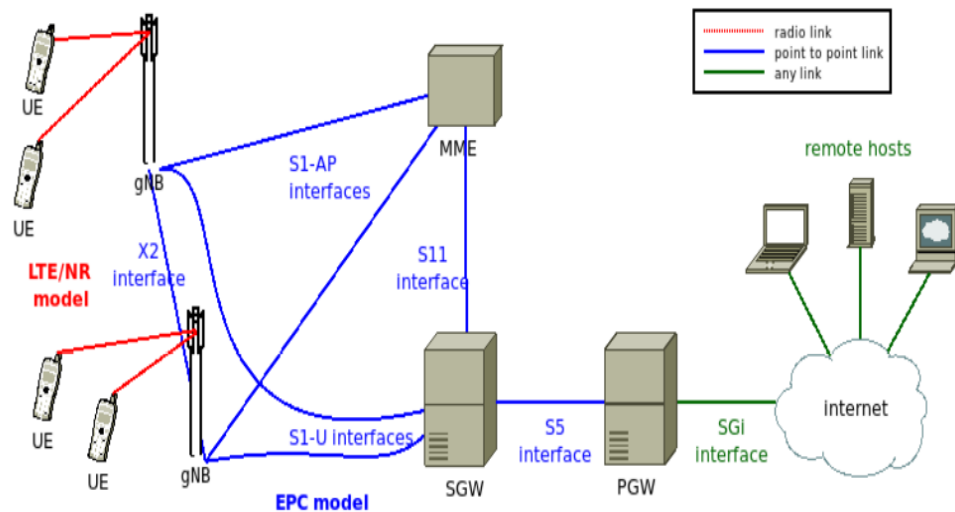
Source: <https://gerrit.o-ran-sc.org/r/admin/repos/sim/a1-interface>

Docs: <https://docs.o-ran-sc.org/projects/o-ran-sc-sim-a1-interface>

Wiki: <https://wiki.o-ran-sc.org/display/RICNR>

Cellular Network Simulator: ns-3

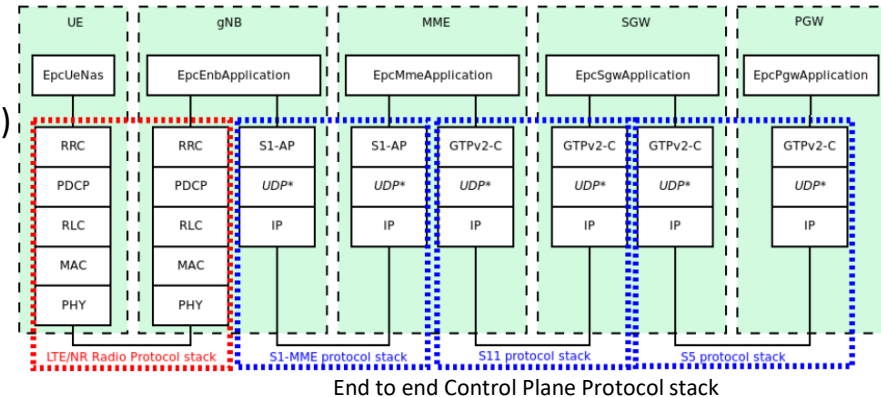
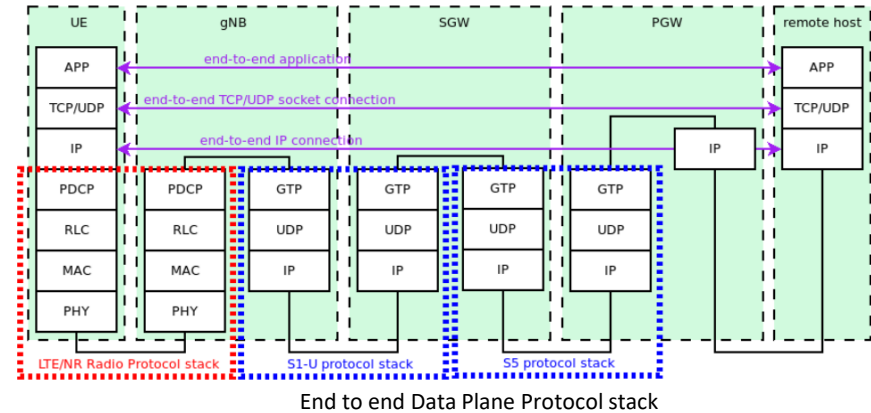
- ns3 provides models of how packet data networks perform, and provides a simulation engine for users to conduct simulation experiments
- Allows the prototyping of algorithms for
 - Radio Resource Management
 - Self Organized Networks
 - Inter-cell Interference Coordination
- PHY layer abstraction
- Realistic Data Plane Protocol stack model
- Simplified Control Plane model
- Simplified EPC- One MME and one SGW and PGW.
- KPIs availability at different levels:
 - Channel- SINR maps, pathloss matrices
 - PHY- TB tx/rx traces, RSRP/RSRQ traces
 - MAC-UL/DL Scheduling traces
 - RLC and PDCP – Time averaged PDU Tx/Rx stats
 - IP and application stats- Flow monitor, PCAP traces



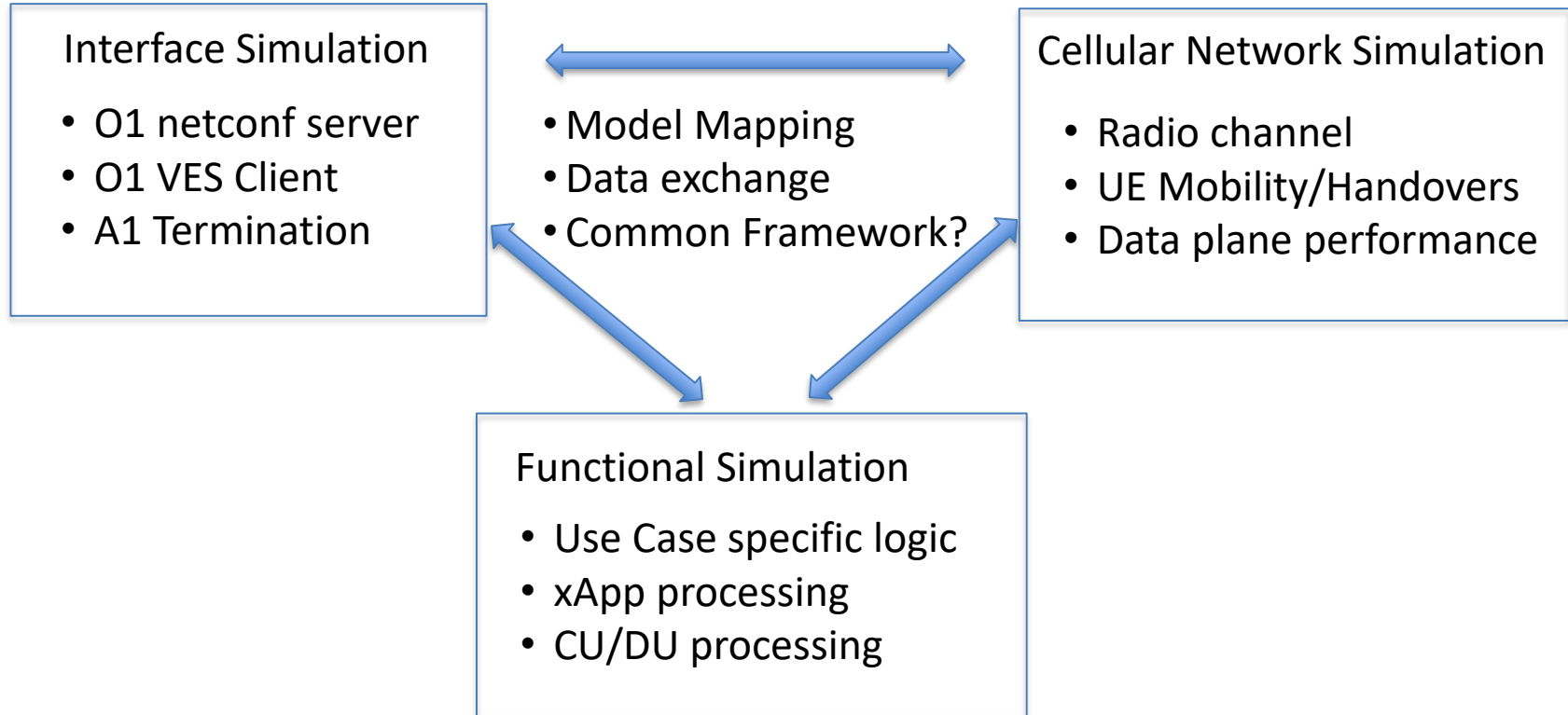
End to end overview

ns3 Design Choices

- Data Plane Protocol stack model
 - Realistic RLC, PDCP, S1-U, X2-U
 - Allow proper interaction with IP networking
 - Allow end-to-end QoE evaluations
- Control Plane Protocol model:
 - Realistic RRC model
 - Simplified S1-C, X2-C and S11 models
 - Realistic S1-AP, X2-C, S5
- Simplified EPC
 - One MME and one SGW
 - SGW and PGW in the same node (no S5/S8 interface)
- Focus on connected mode
 - RRC connected, EMM Registered, ECM connected



E2E flows: RAN Interfaces + Cell Network



- Different use cases need different abstractions for efficient implementation -> expect RAN Simulator variations
- There is opportunity to create common building blocks
 - Yang models for RAN
 - Netconf server/client building block
 - VES stdnDefined domain and schemas for O1
 - Network topology models
 - Common formats/lists for PM KPI, FM fault
 - Integration of ML methodologies
 - Abstractions of RAN functionality

RAN Simulator Enhancements

- Modification of ONAP RAN-Sim netconf server
- Extension of OSC sim for use case logic
- Simulation of Near-RT RIC / xApp to complement SMO/rApp implementation
- Simulation support for RU endpoint and configuration
- Simulation support for O2 interface and cloud functionality
- Transport network effects
- Enhancement of cellular network simulation
- Common framework for combining simulators

RAN Simulation areas

Interface simulation

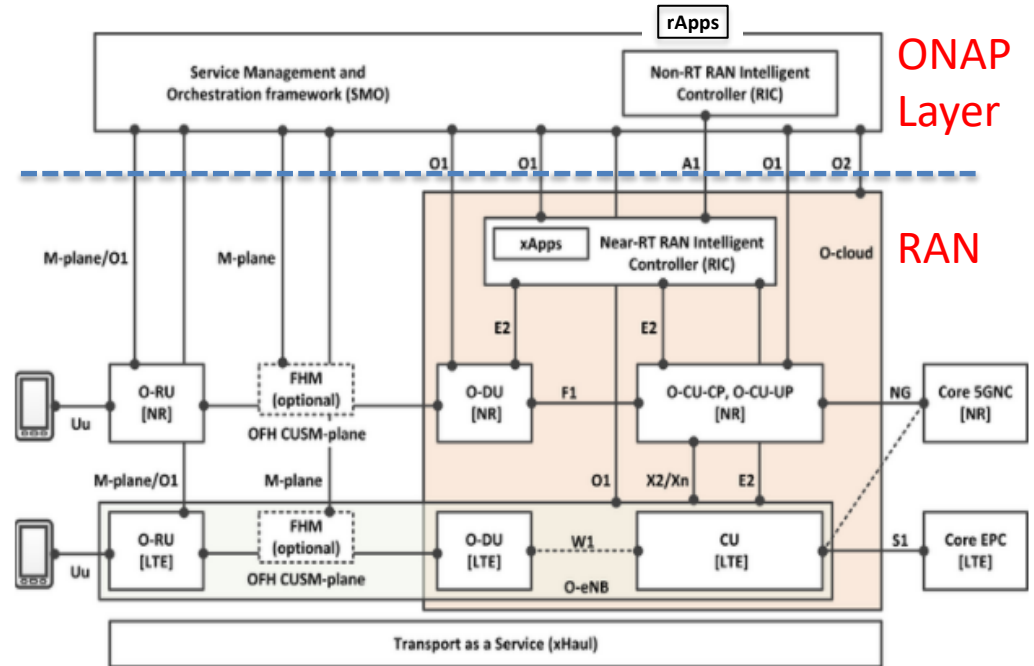
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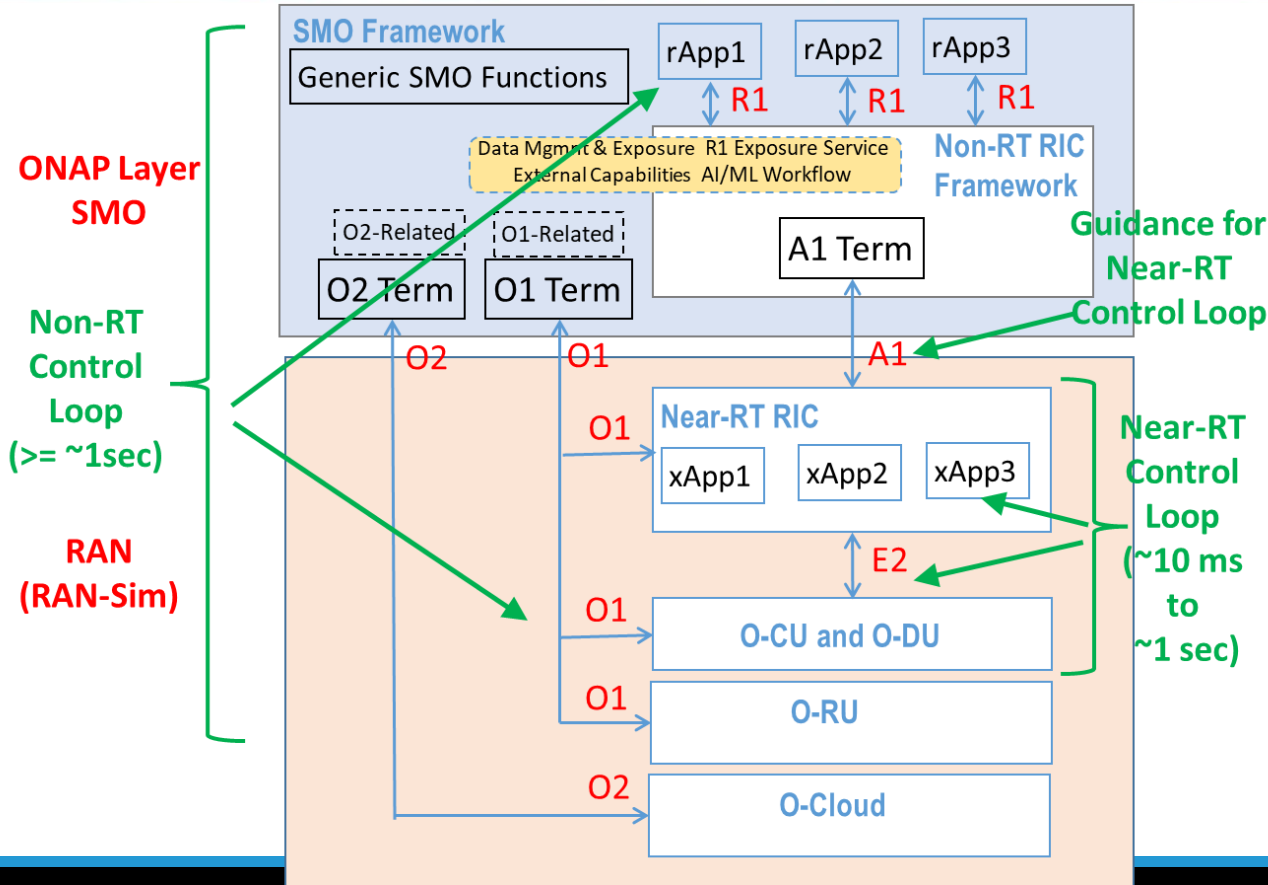


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Backup

O-RAN Control Loops



- Non-RT Loop
 - Time scale: ~ secs/mins
 - Direct config of CU/DU
 - Policy Guidance, Coordination
- Near-RT Loop
 - Near-Real-Time (~100ms)
 - Based on E2 service models
- SON examples
 - Non-RT: Changes based on operational state, averaged behavior
 - Near-RT: Changes based on radio channel, mobility