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RAN Simulation for ONAP / SMO Use Cases

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Jan 13, 2022

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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

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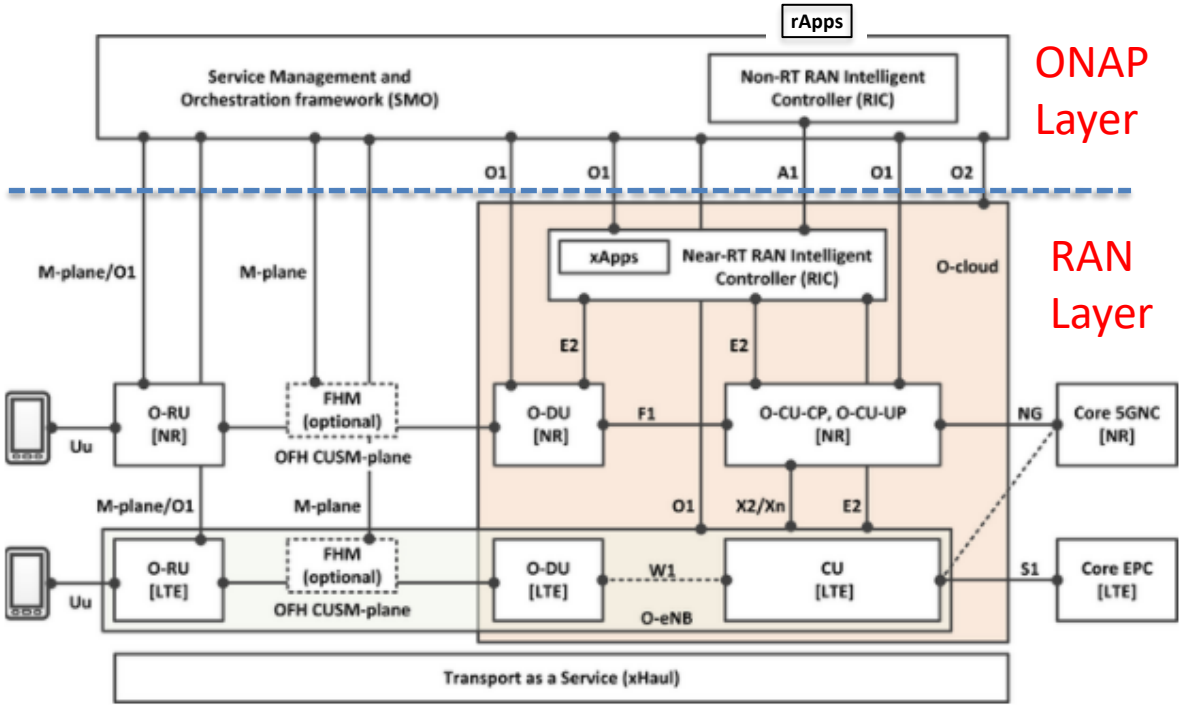
Use Case functions implemented:

- 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

Ref: Dec 15, 2021 - https://www.o-ran.org/blog/2020/10/24/o-ran-global-plugfest-2021-demonstrates-stronger-ecosystem-and-maturing-solutions

RAN Simulation areas

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Interface simulation

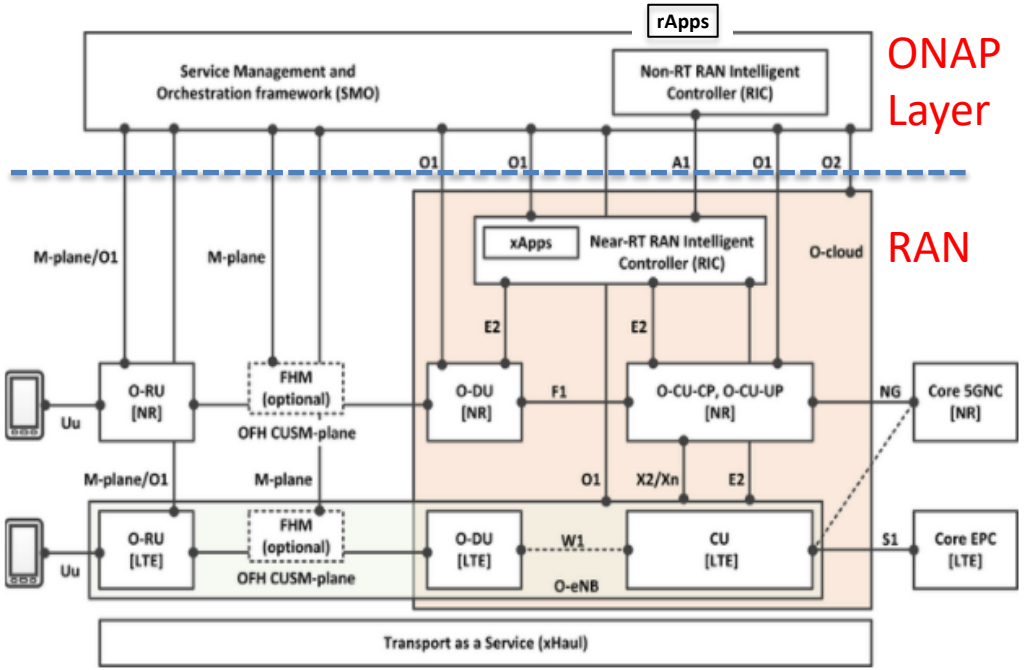
- Focus on O-RAN interface
- e.g., O1 netconf server, VES client
- Configuration of RAN (O1, M-plane)
- Data from network (O1, M-plane)
- Guidance to xApps (A1)
- Cloud config/data (O2)

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)



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Test-Stubs / Simulators / Emulators

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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

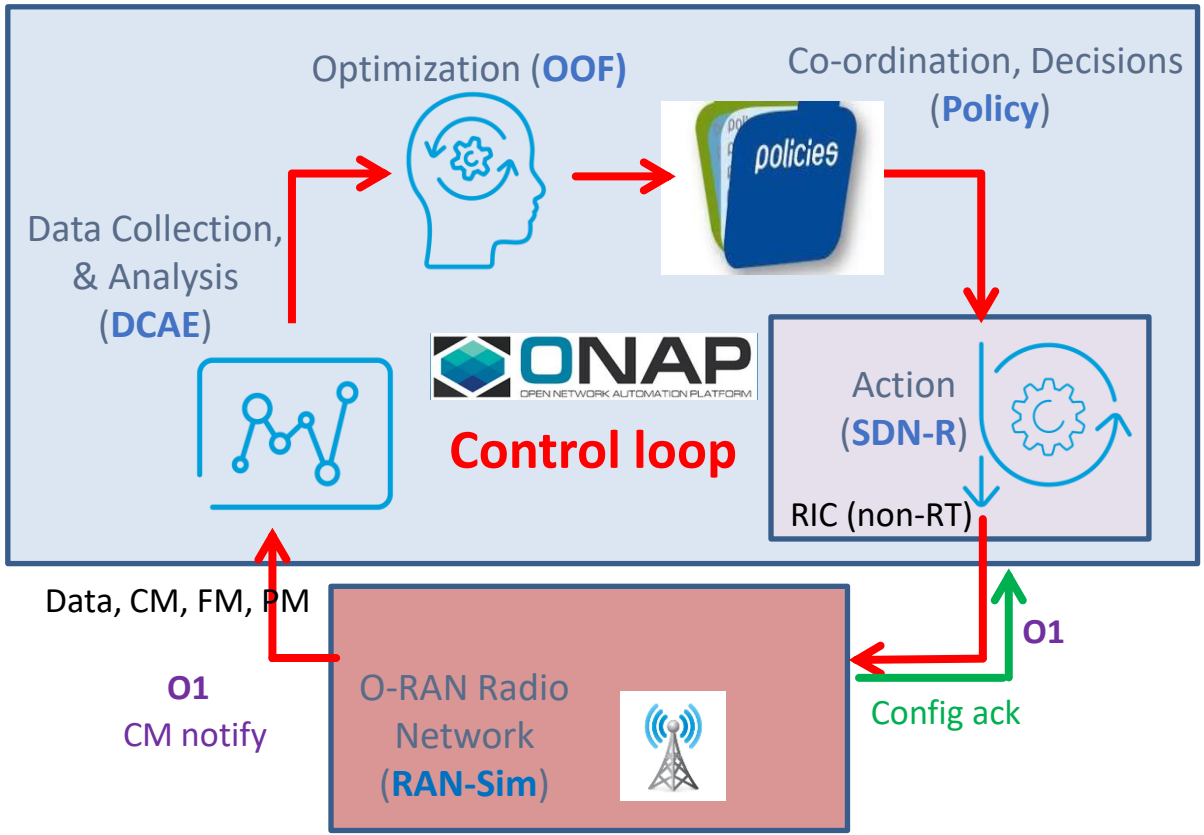
- Simulator/Emulators can only be an approximation of “The Real Thing”
  - Usefulness of a simulator is entirely subjective – depending on the consumer’s custom usecase/requirements
    - Best ones are customizable/extensible/configurable/model-driven
  - Trade-off: advantages vs realism/fidelity
- Advantages 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



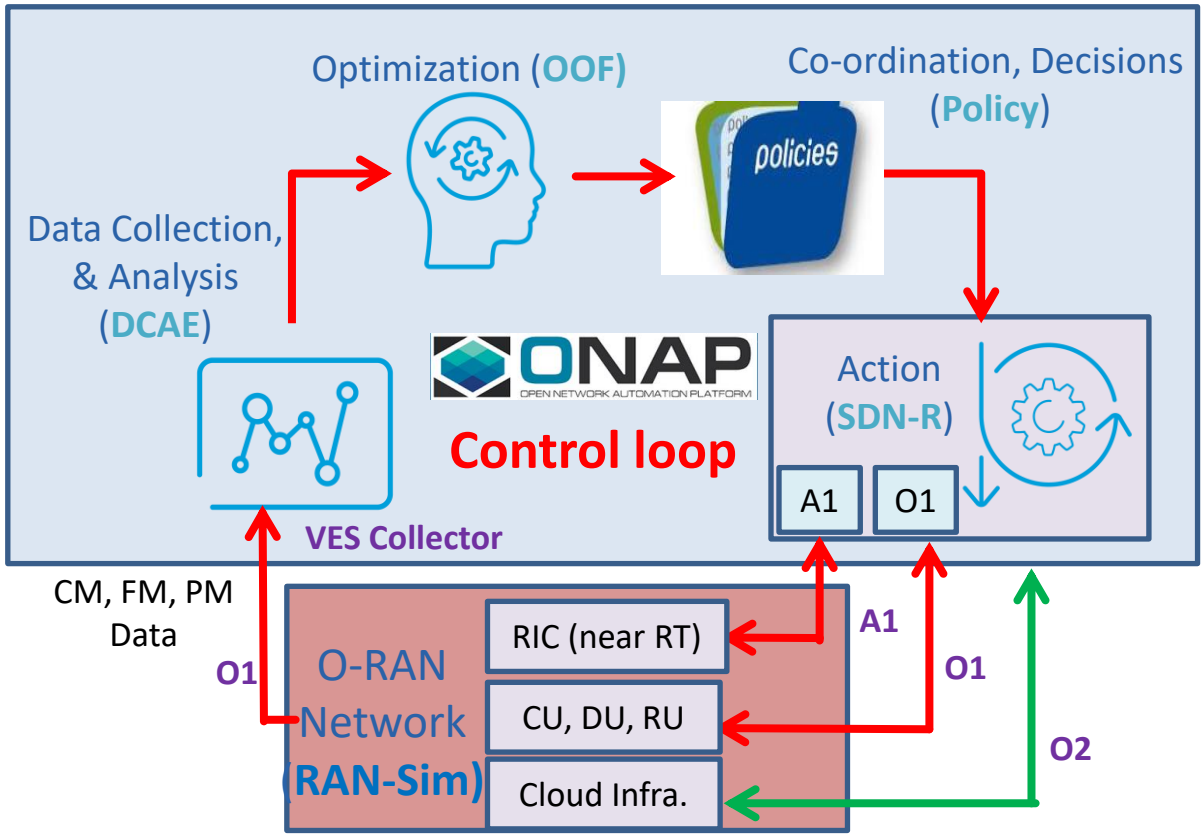
- SON ⇔ Control Loop (CL)
- Companies can use framework to add proprietary SON solutions, including optimization algorithms, etc.

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

<u>Data flows</u>

- 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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- OOF-SON use case has built a foundation for ONAP/O-RAN integration
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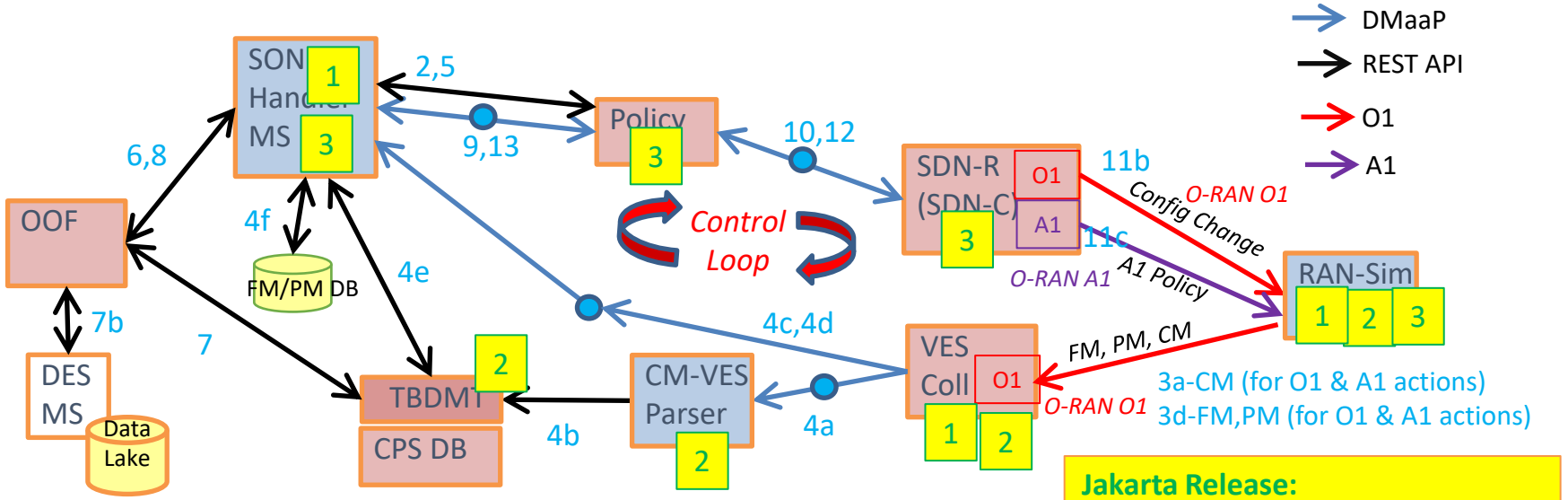
<u>Data flows</u>

- 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)

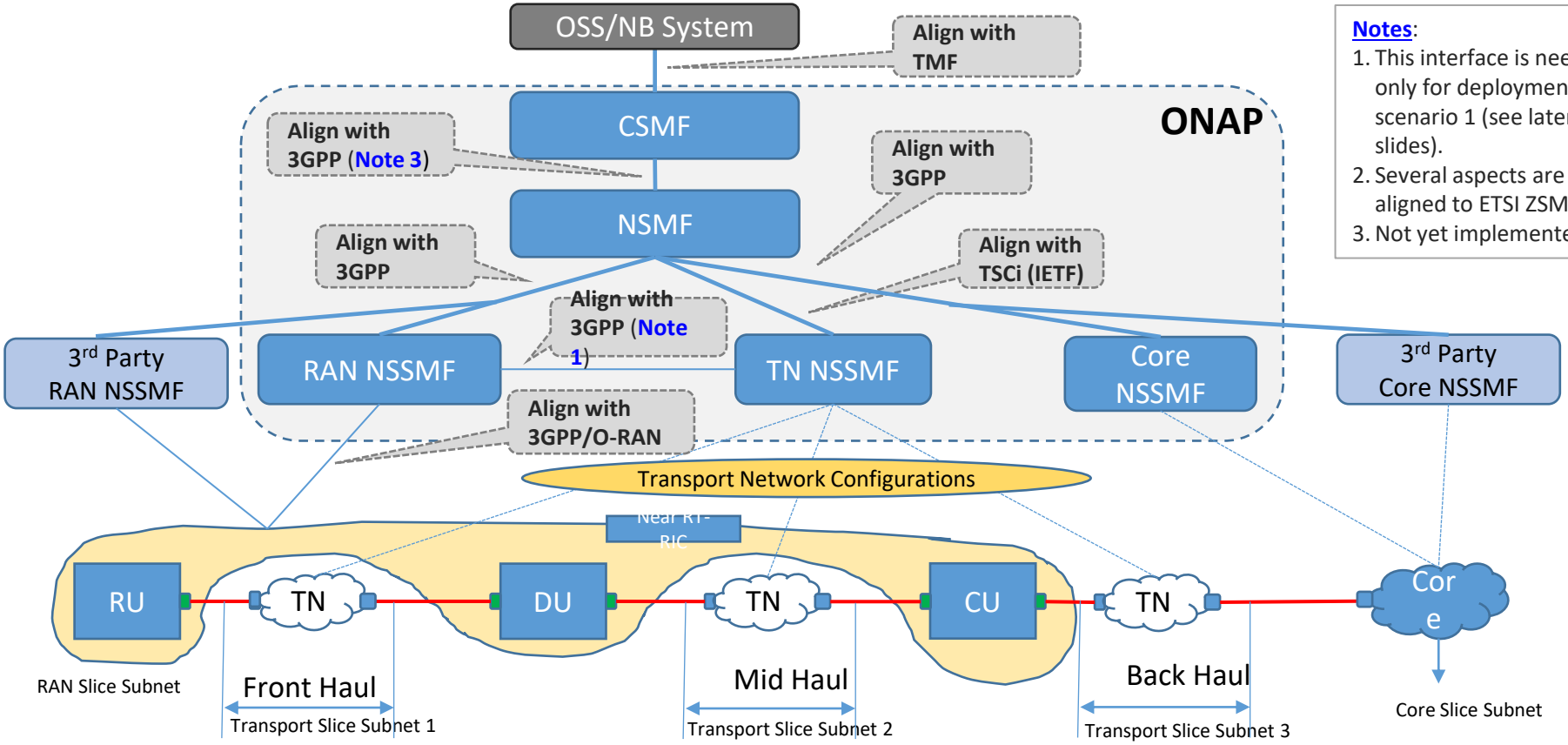


Steps 3a,4a,4b,4c: CM data received from RAN, update of state in CPS DB
Steps 3d,4d: FM/PM data received from RAN, processing in SON MS
Steps 2,4e,4f, 5: SON MS analyzes need for optimization
Steps 6,7,7b,8: Optimization using OOF
Steps 9,10,11b,11c: Automated action to make change in RAN (O1 and A1)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

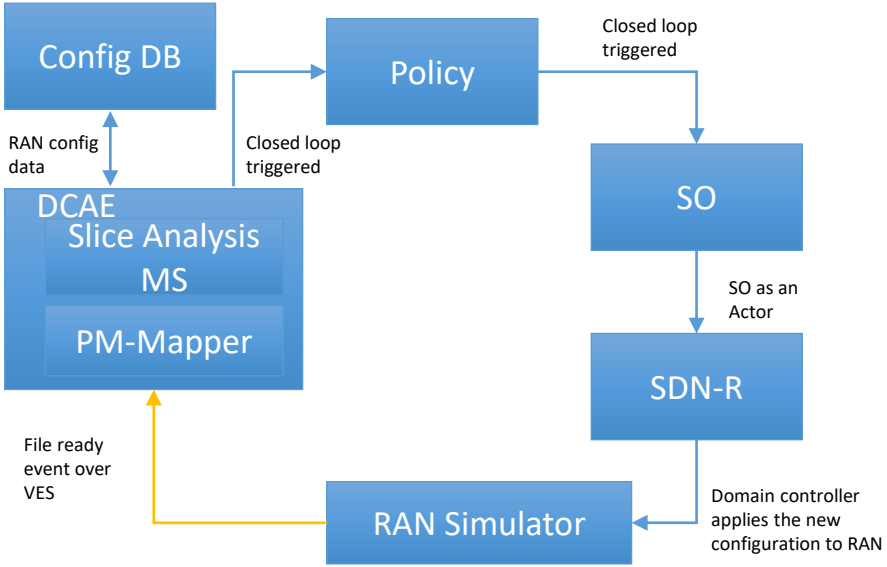
E2E Network Slicing: Architecture & Interfaces



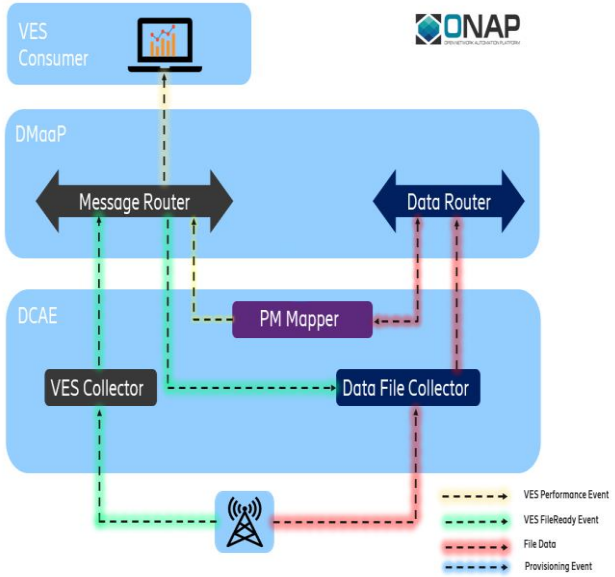
Notes:

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

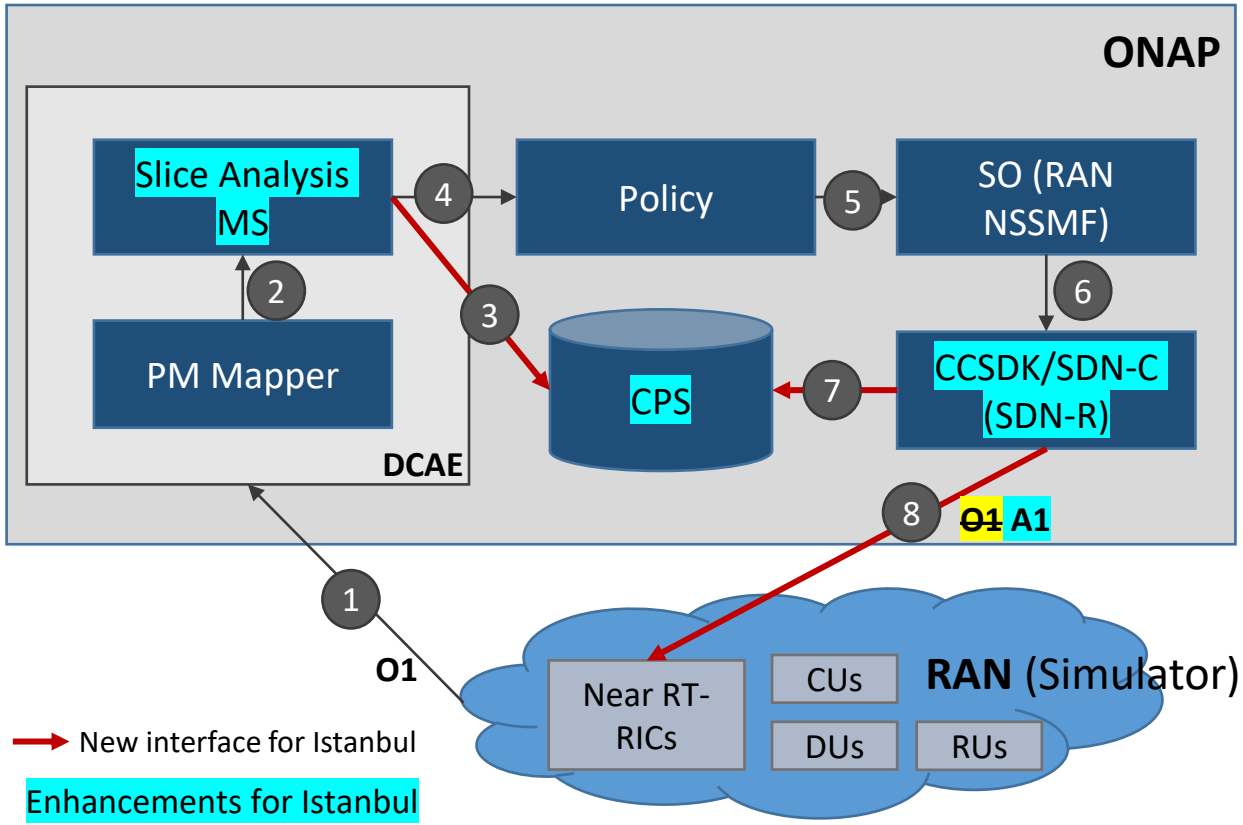


Data flow from RAN n/w to DCAE-Slice Analysis MS



Ref. ONAP wiki

E2E Network Slicing Closed Loop: Istanbul Release



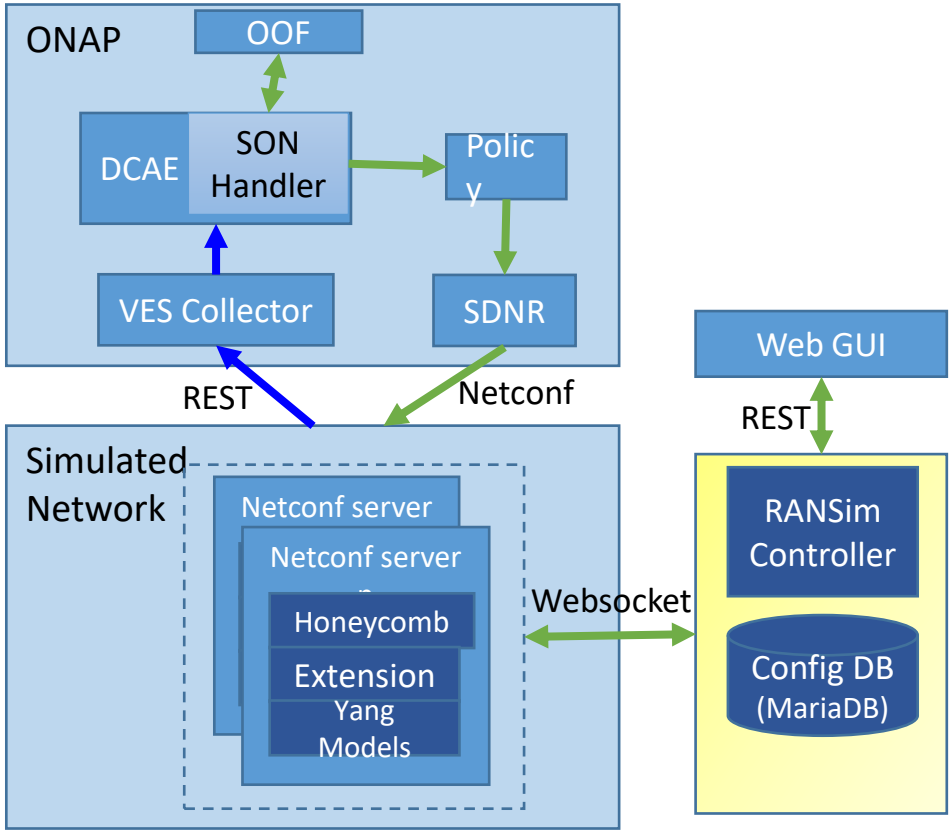
- The PM data collected from RAN in Step 1 is DL/UL PRB used for data traffic.
- The configuration update determined by Slice Analysis MS and triggering Policy in Step 4 is slice specific throughput guidance for Near-RT coverage area (i.e., at Near-RT RIC level).
- Step 8 is over **O1** in Honolulu,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

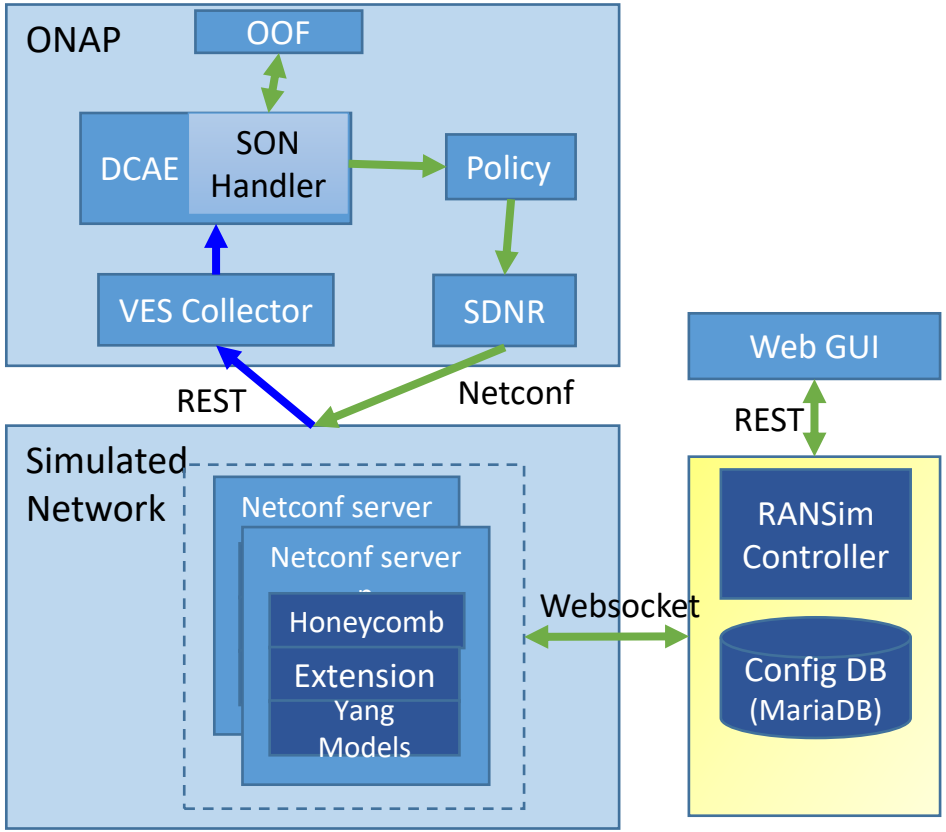
RAN-Simulator (RAN-Sim)

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
- Controller
  - Send message to corresponding Netconf Server about the collision/confusion
- Netconf Server
  - Send configChangeNotification to SDNR
  - **Send FM/alarm message to VES Collector for collision/confusion. Thus the control loop starts**
- GUI
  - Show the modified PCI values
- 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

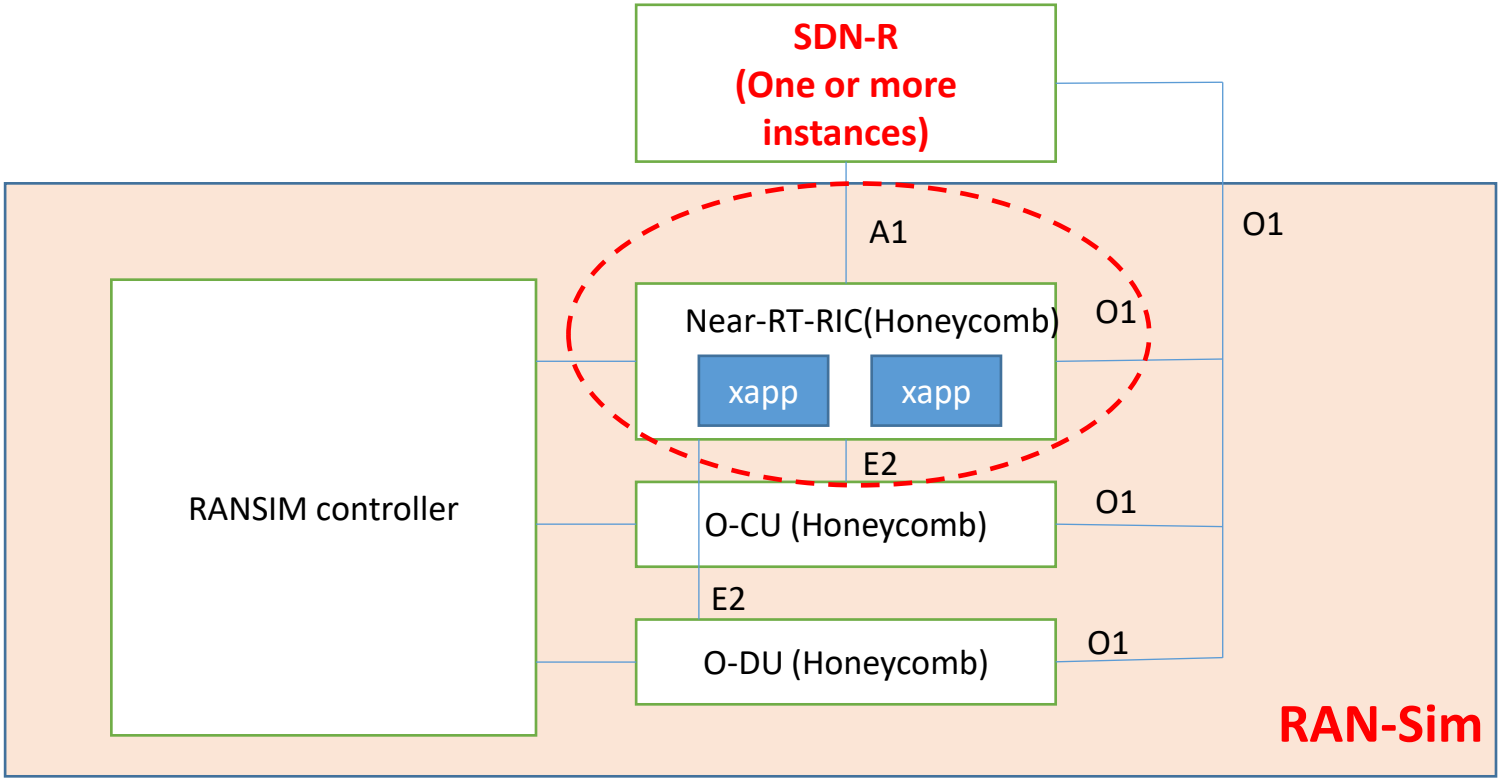
Approach for RAN Simulator (RANSim) – Dublin - PM



- 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



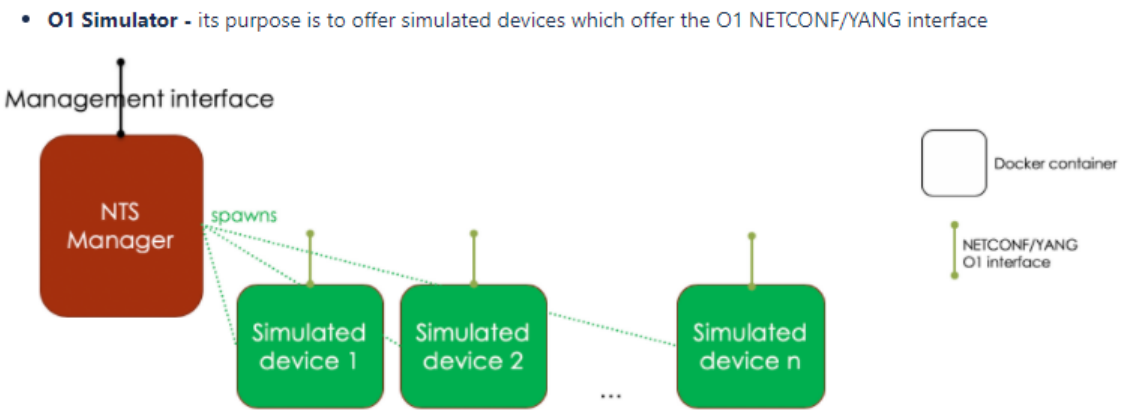
Problem: RAN-Sim Upgrade is Needed

- 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)

O1 simulator in OSC sim

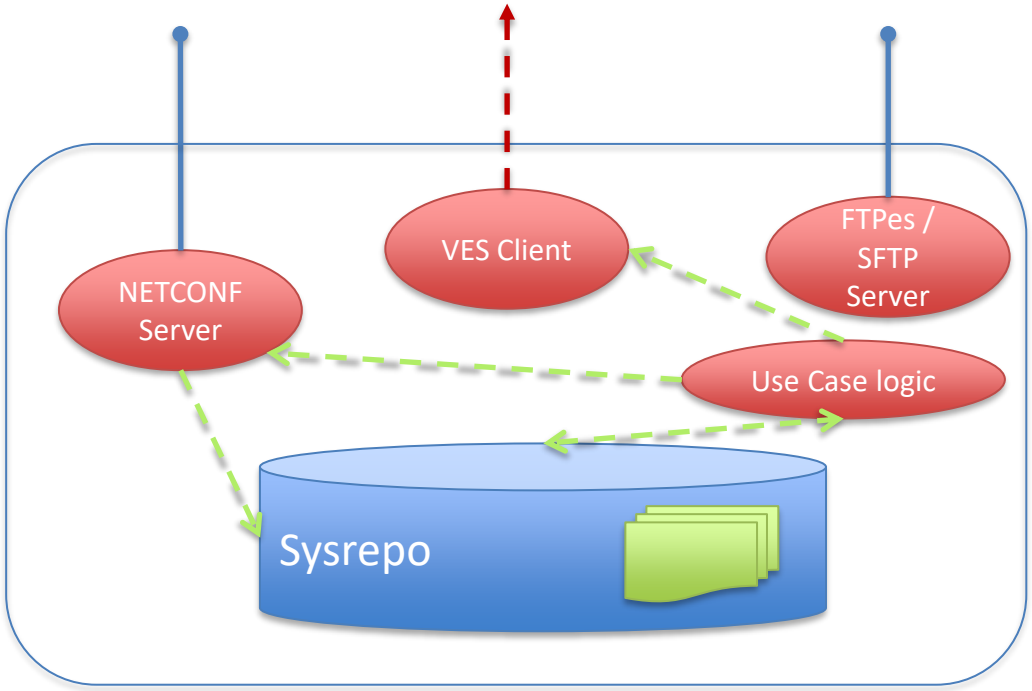
O-RAN Software Community (OSC) sim project

Ref: https://wiki.o-ran-sc.org/display/SIM/Architecture
Contact: Alex Stancu

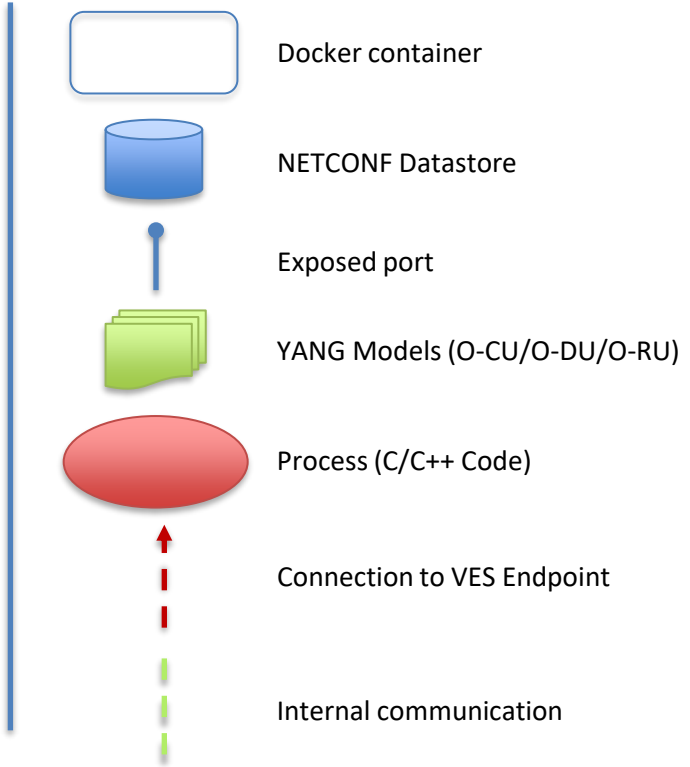


- Simulated devices in Simulated RAN are netconf (netopeer) devices representing CU/DU O1 instances with CU/DU yang models
- NTS (Network Topology Simulator) Manager uses netconf to connect to devices using yang model of simulation entities
- NTS also has NB netconf interface for external entity (e.g.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

O-RAN-SC O1 Simulator architecture



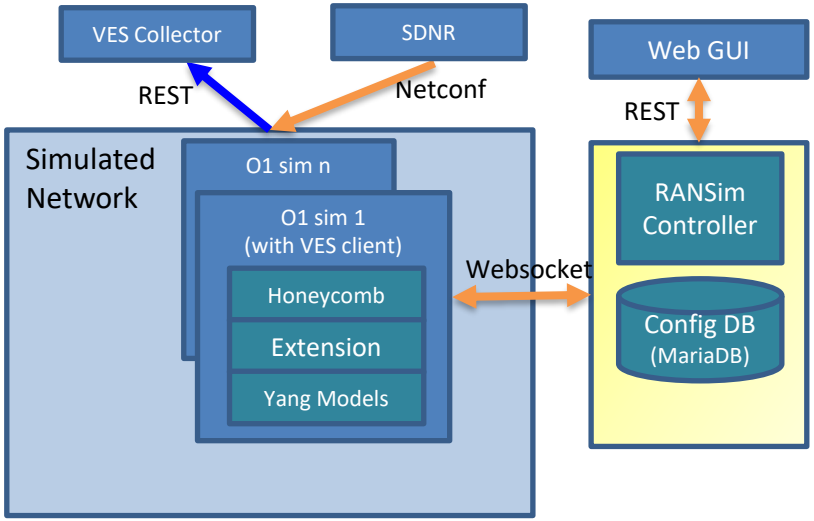
Simulated NF (O-CU/O-DU/O-RU)



NETCONF Server framework – Netopeer2

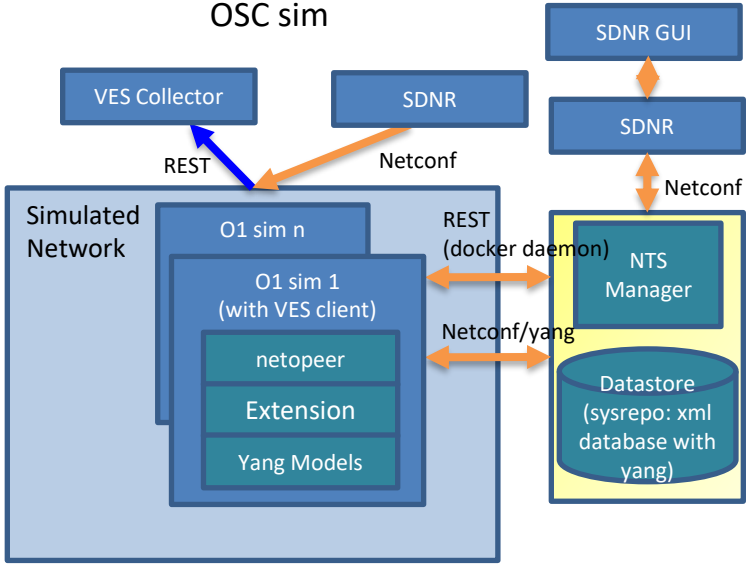
Comparing RAN-Sim and OSC sim

RAN-Sim



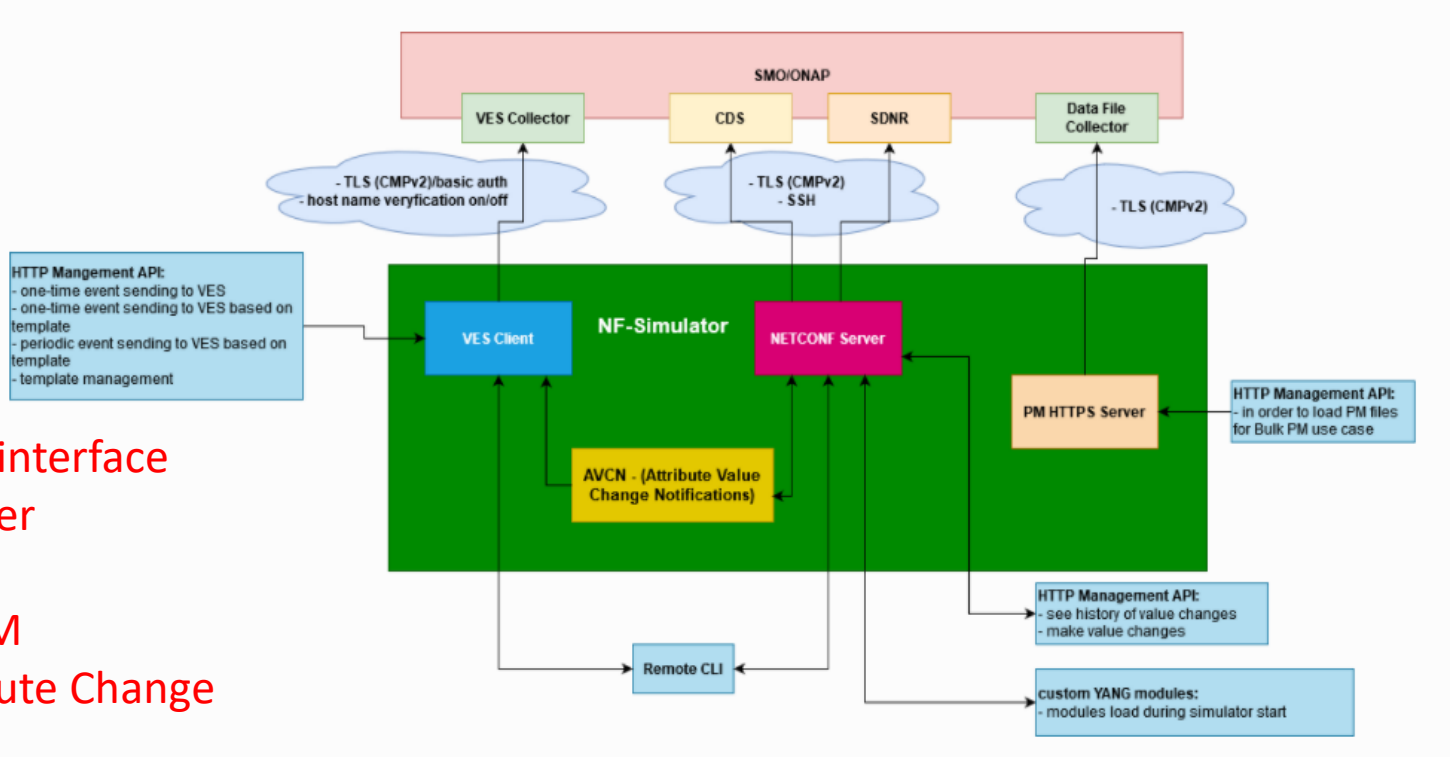
- RAN-Sim was developed for ONAP Use case
- Has use case specific logic (e.g. analyze cell relations and generate fault message)
- Netconf devices are mounted manually
- VES message details are generated in Controller as per usecase logic

OSC sim



- 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

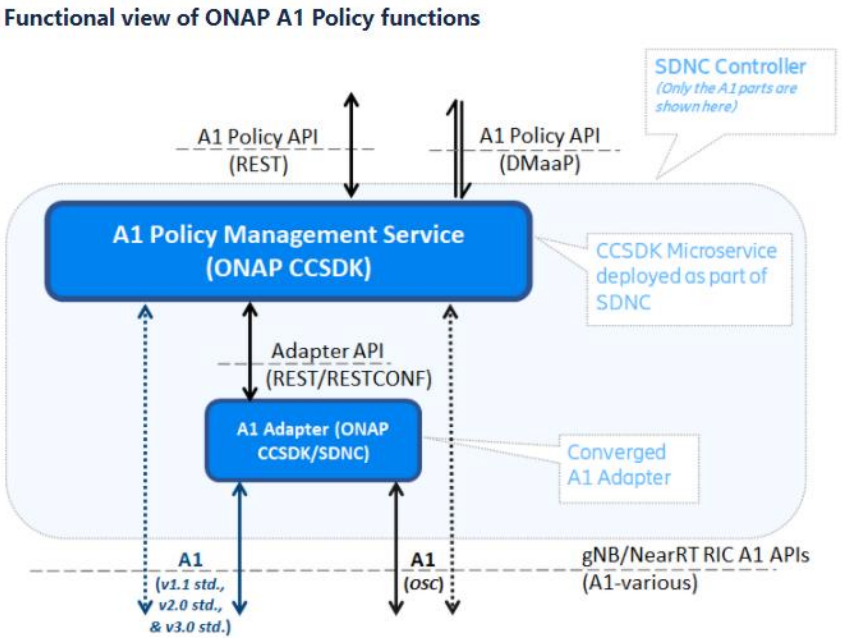


- xNF with O1 interface
- Netconf server
- VES Client
- File-based PM
- Config Attribute Change

https://docs.onap.org/projects/onap-integration/en/latest/simulators/nf_simulator.html

A1 Functions in ONAP / OSC

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



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

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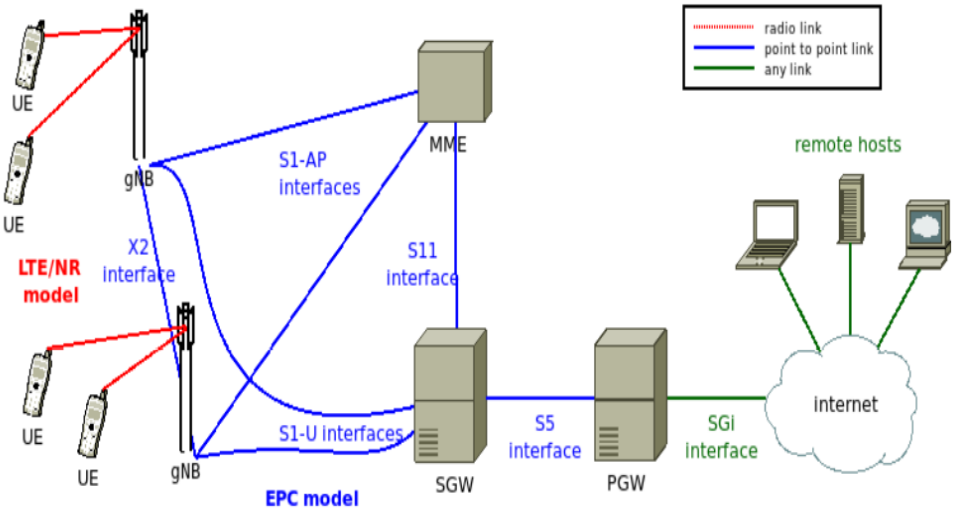
Stateful A1 test stub for "South-end" of A1 Interface

- 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

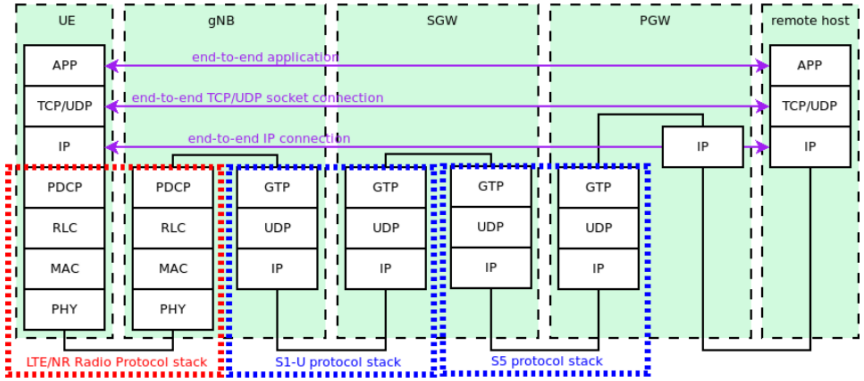


End to end overview

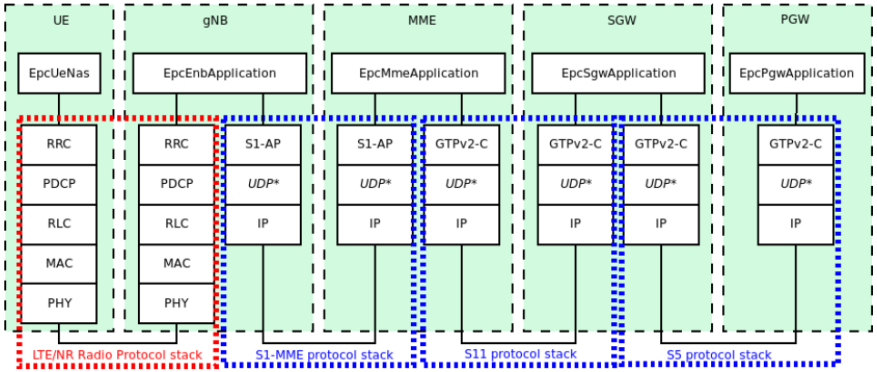
Ref: https://www.nsnam.org/docs/models/html/lte.html

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



End to end Data Plane Protocol stack



End to end Control Plane Protocol stack

E2E flows: RAN Interfaces + Cell Network

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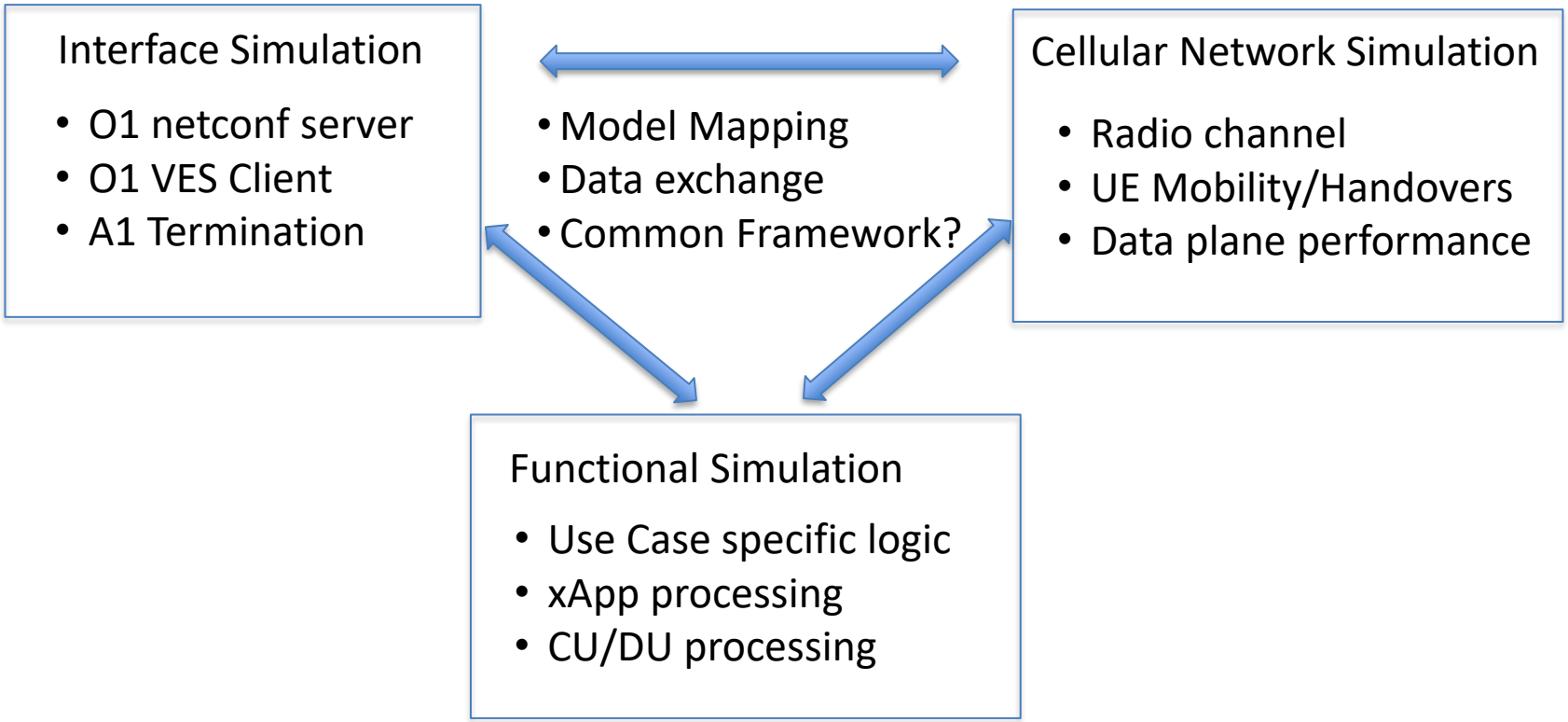

Observations

- 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 stndDefined 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

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- 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

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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)

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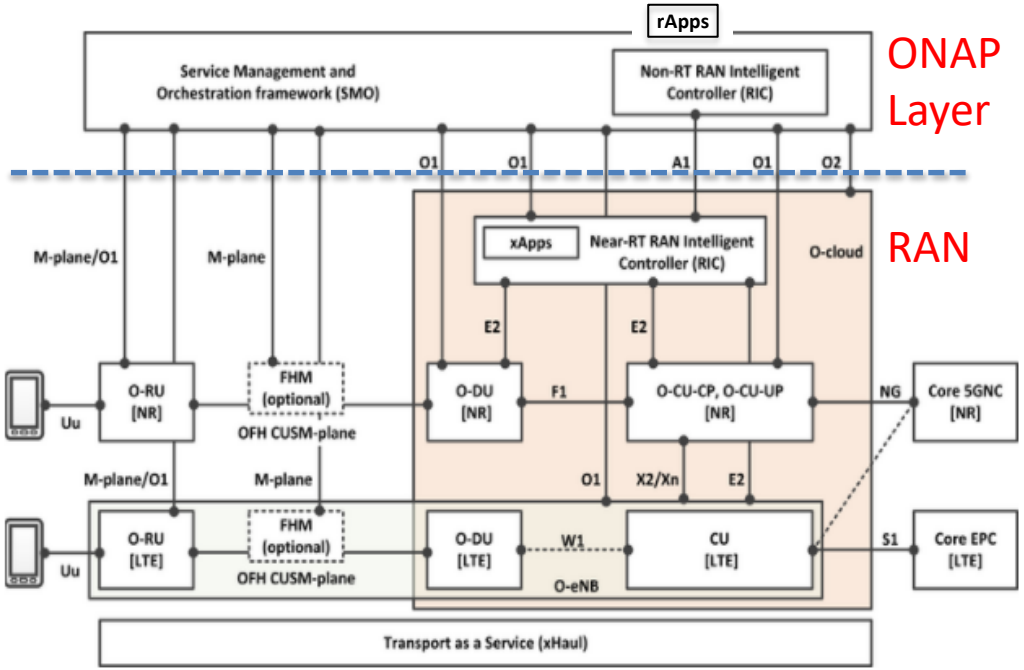
Cellular network simulation

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



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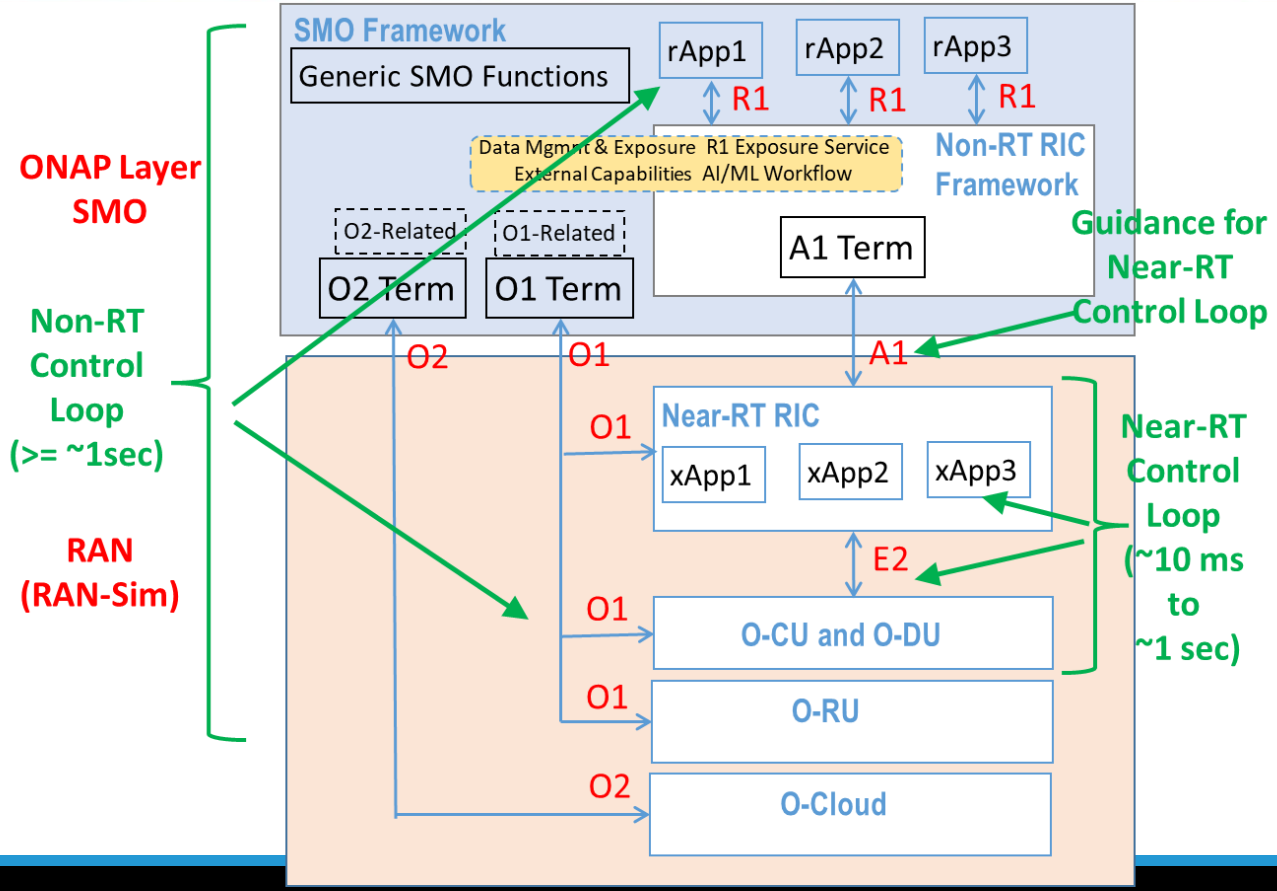
Backup

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