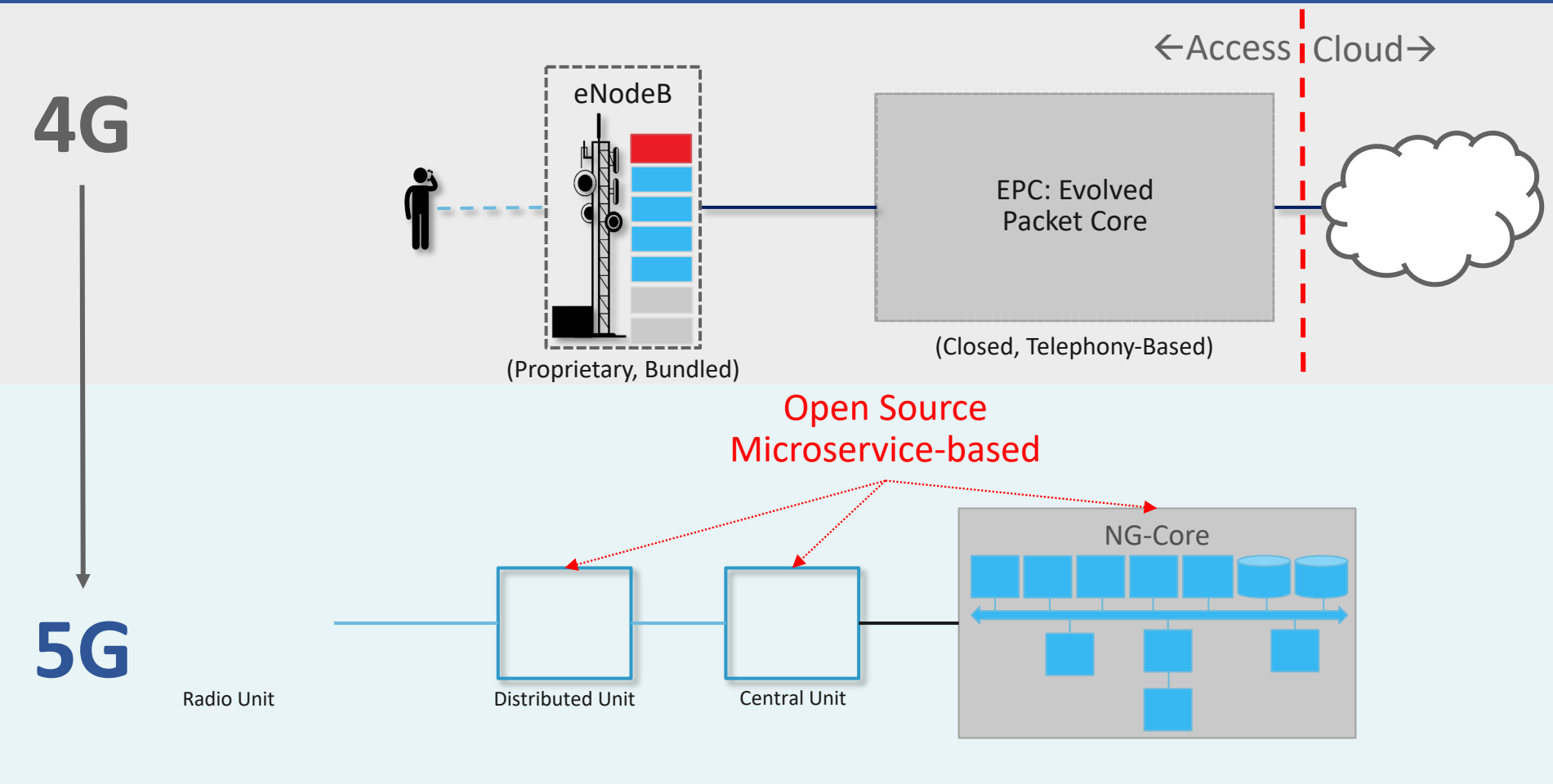
Democratizing 5G

– Open Source and (Much) More –

Larry Peterson
Princeton University
Systems Approach, LLC

Cloudifying the Mobile Cellular Network



Linux Foundation Project

An Open Source 5G Platform for Edge Deployments

AETHER BACKGROUND

Collection of 5G and Edge Cloud Components

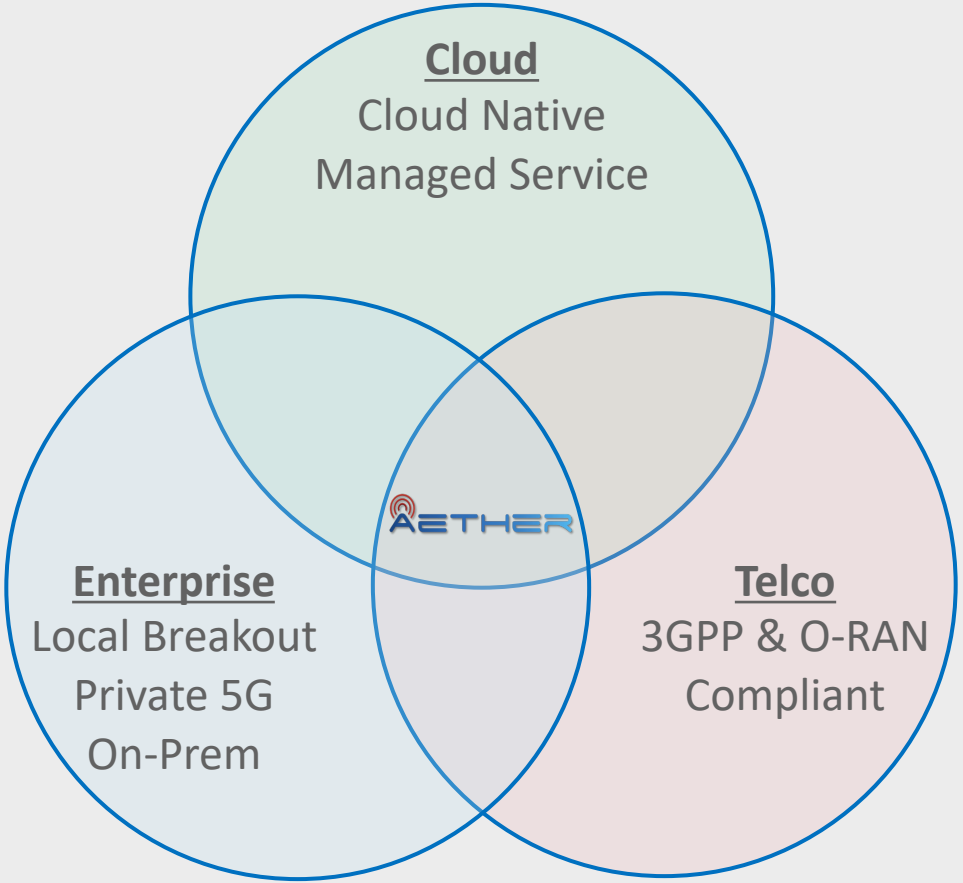
- Collectively provide an end-to-end platform for Private 5G
- Components can also be used independently
  - *SD-Core → Cloud Native 5G Mobile Core*
  - *SD-RAN → Open Source Implementation of O-RAN's nRT-RIC*

History

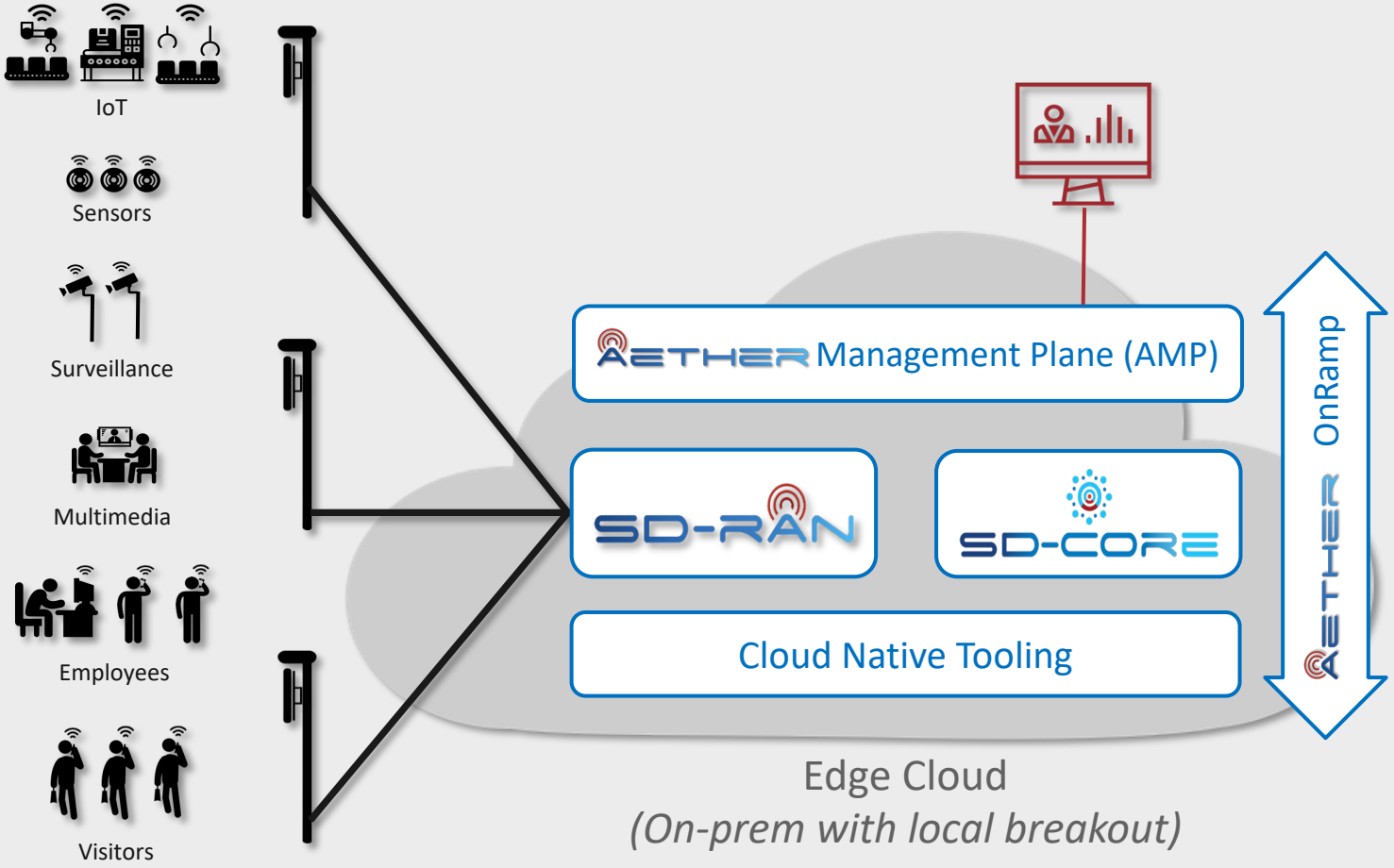
- Incubated at Open Networking Foundation (ONF)
- Funded by a $30M grant from the US Government
- Operated as a Managed Service 2019 to 2023

- Moved to Linux Foundation in February 2024
- Transitioned from a Managed Service to a Deployable Platform

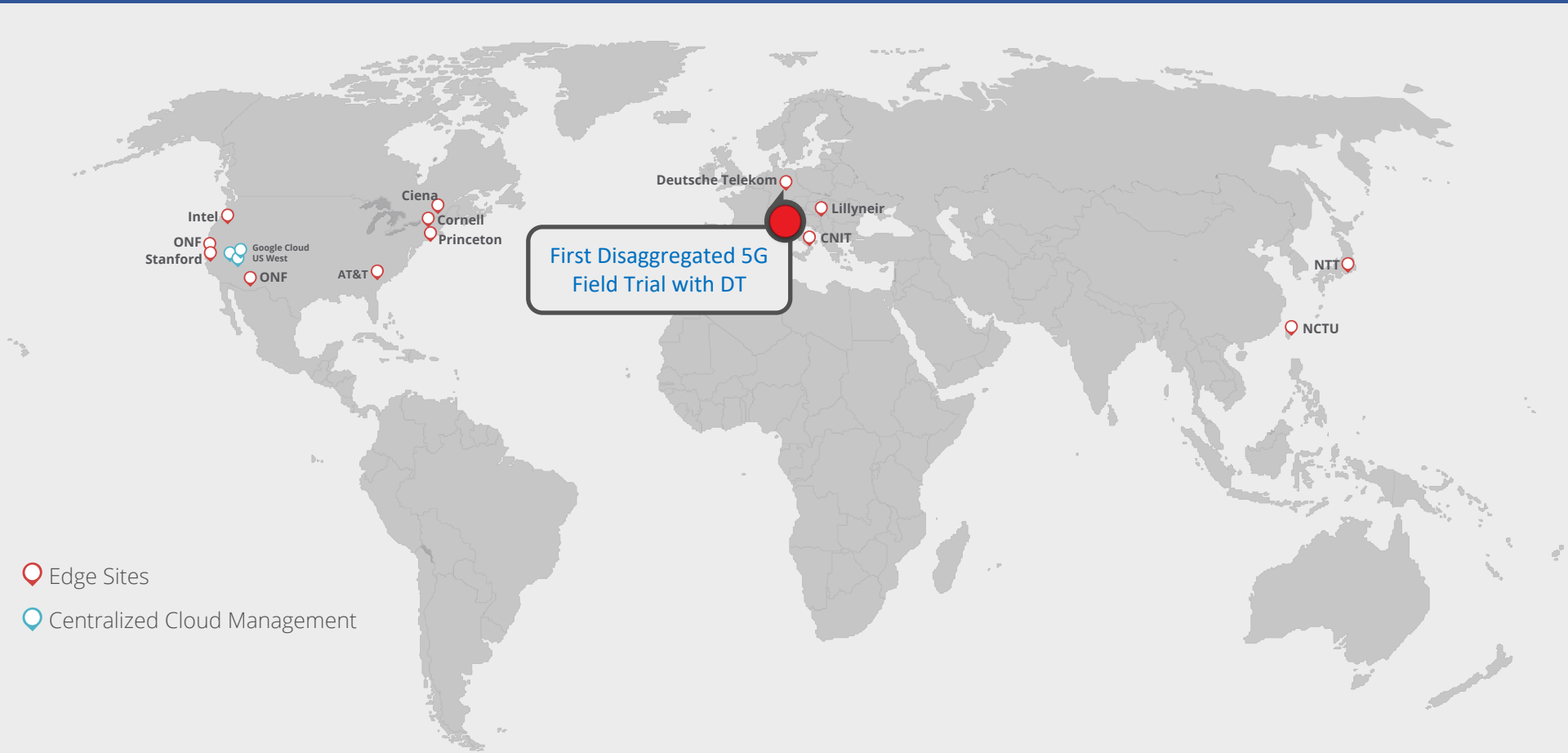
AETHER'S DNA


Cloud
Cloud Native
Managed Service
AETHER
Enterprise
Local Breakout
Private 5G
On-Prem
Telco
3GPP & O-RAN
Compliant

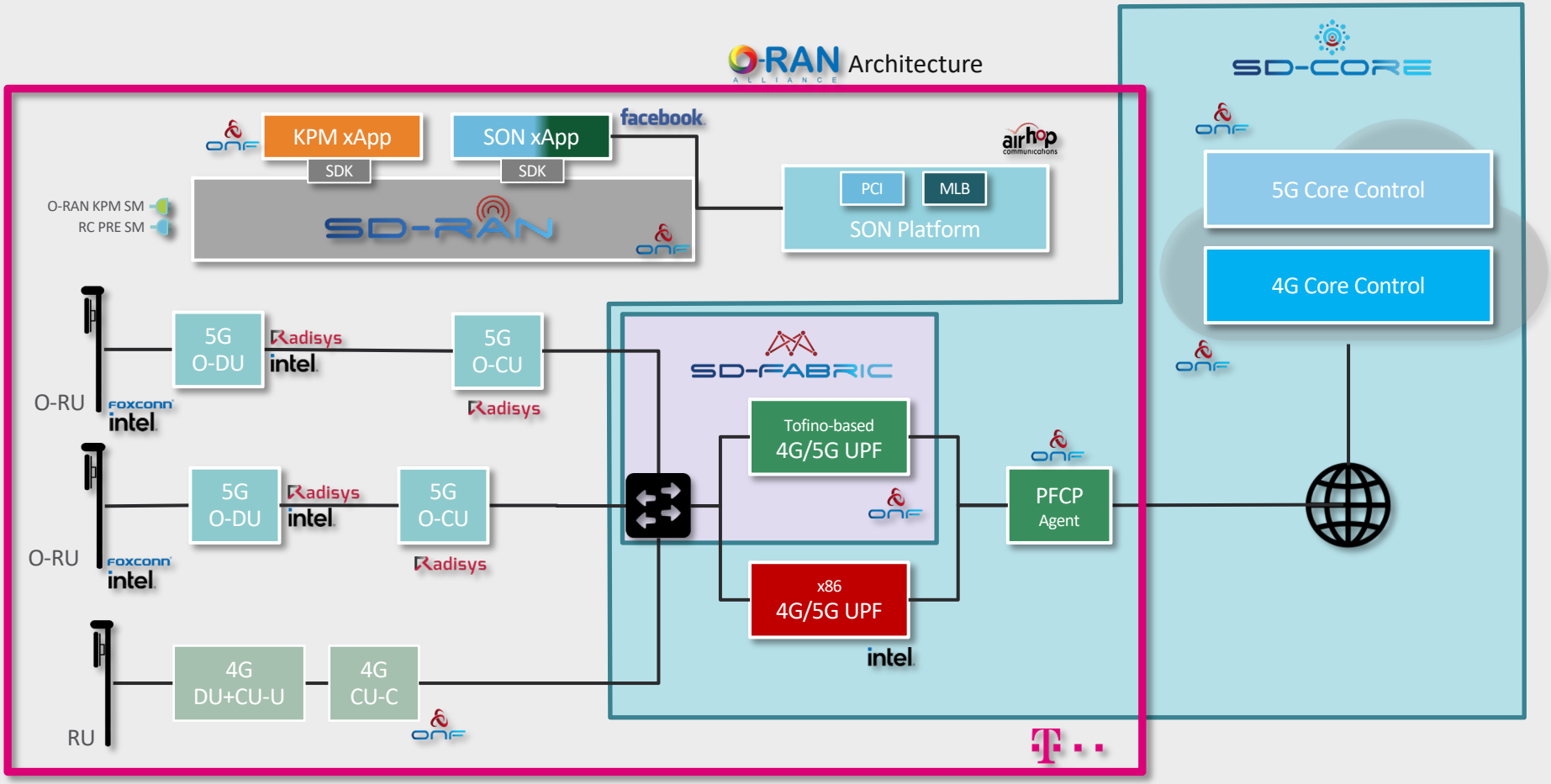
AETHER COMPONENTS



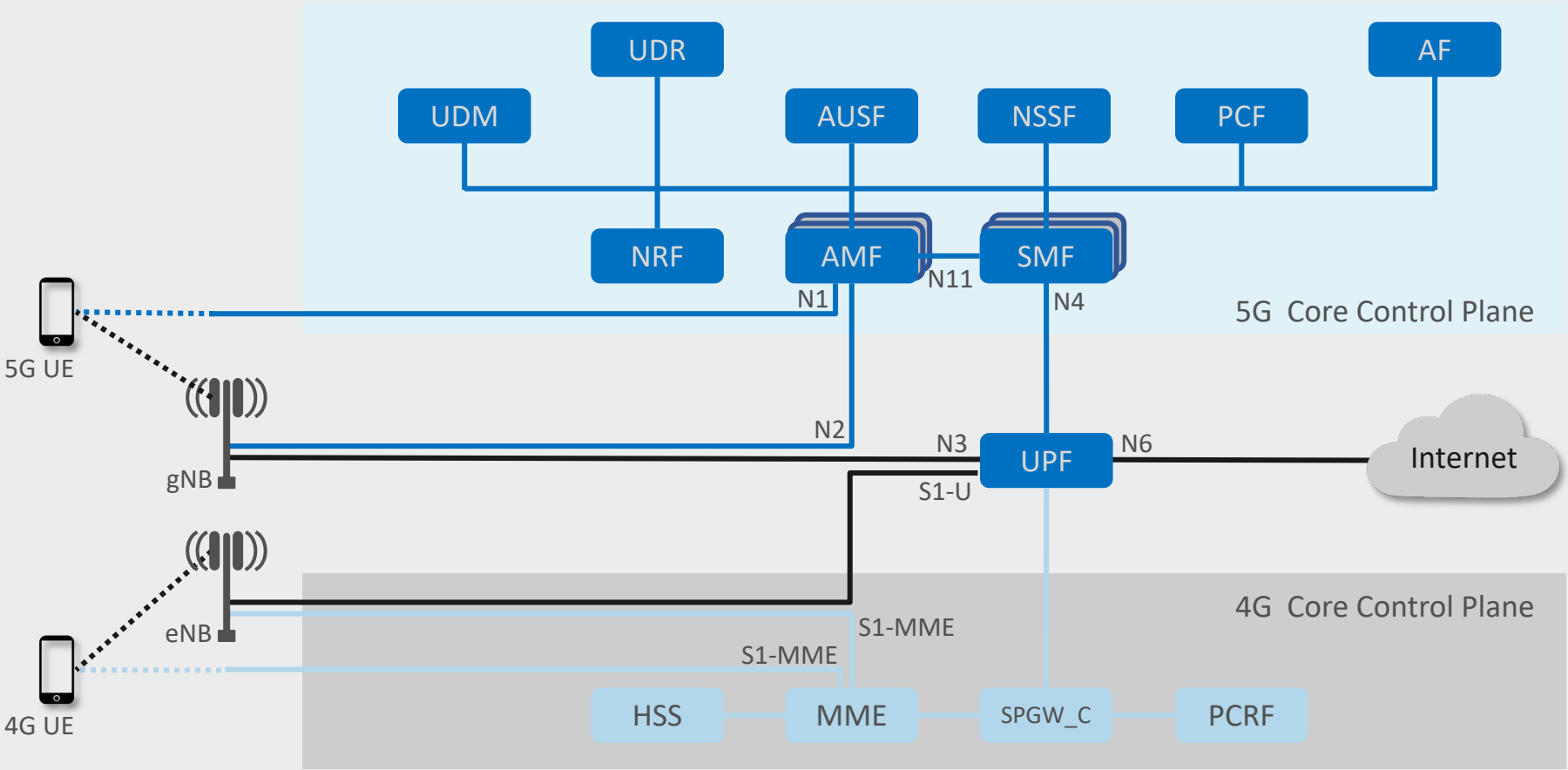
Operational Deployment of Aether



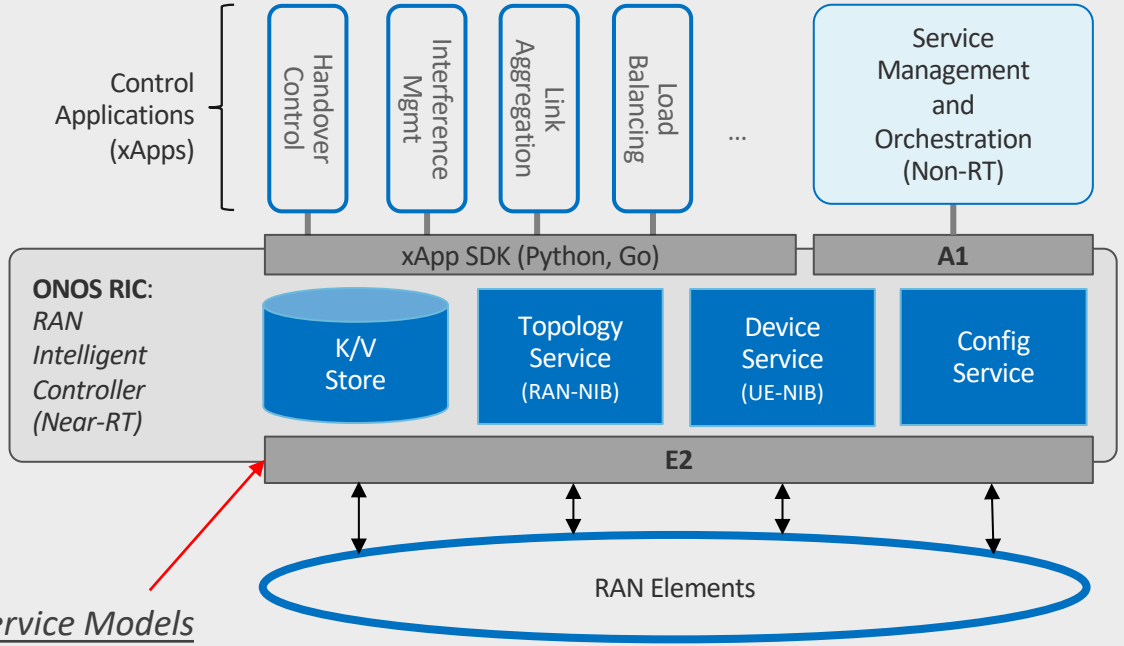
Berlin Open RAN Field Trial



SD-Core: Cloud Native Mobile Core



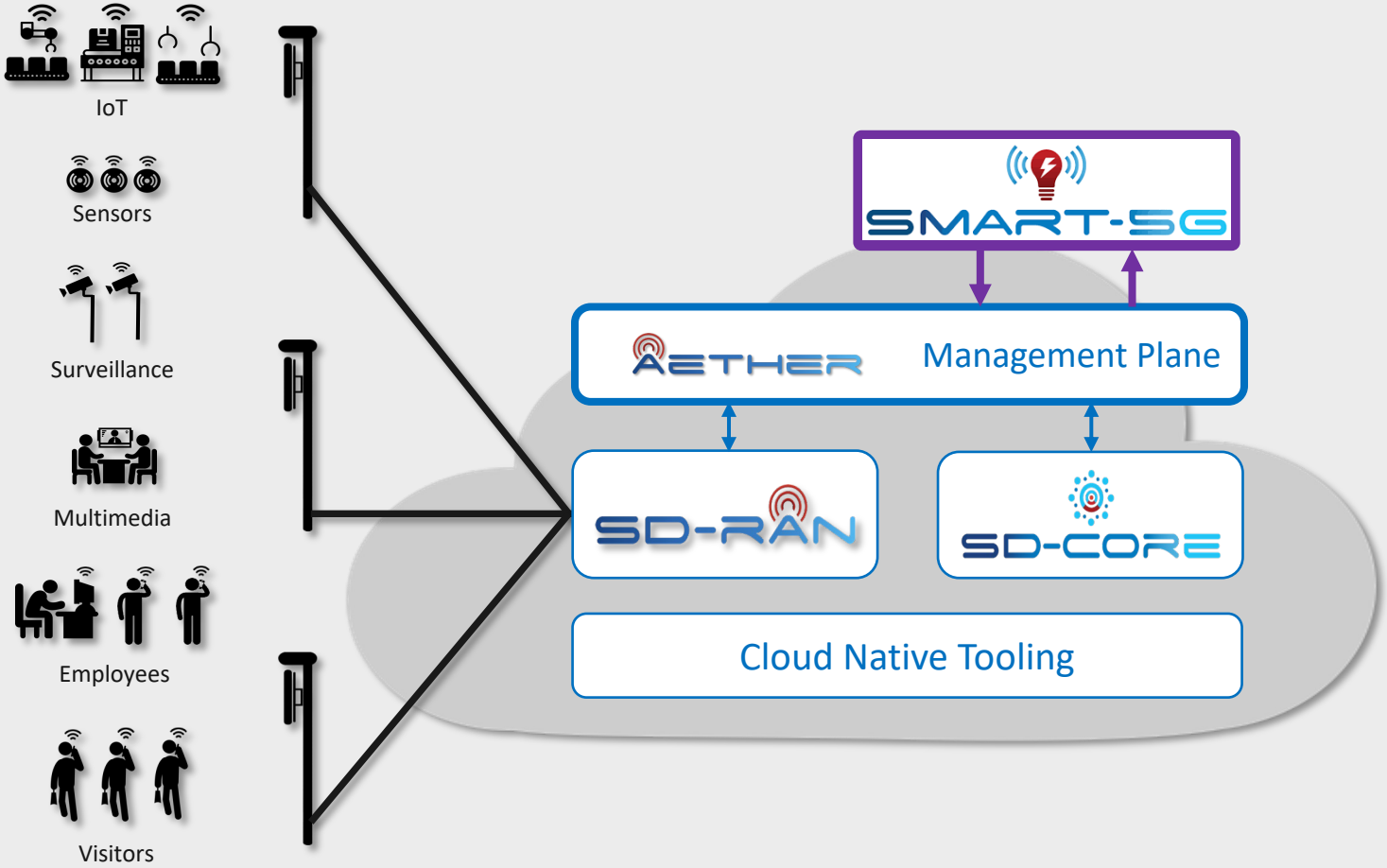
SD-RAN: SDN-Based RAN Control



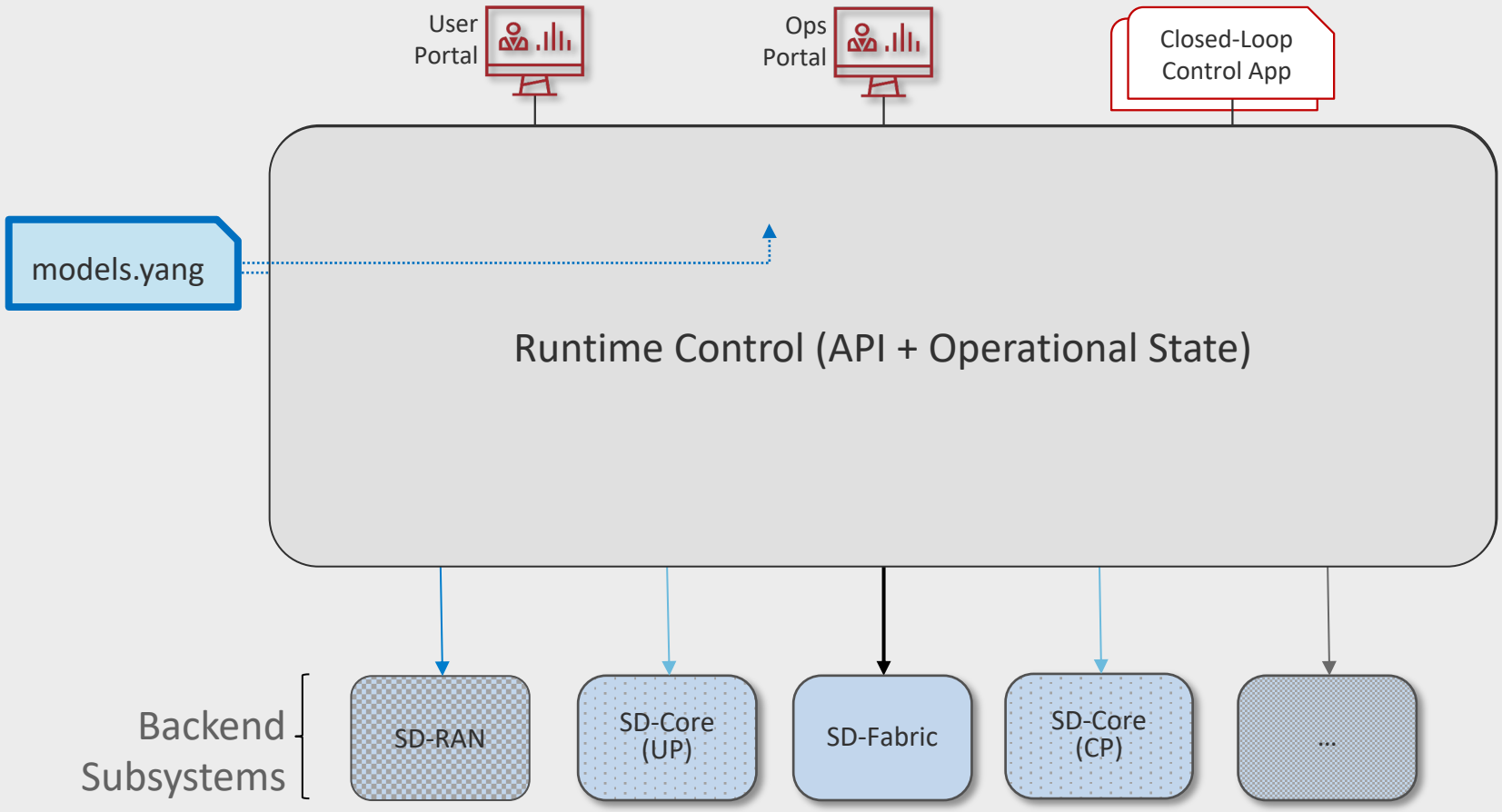
Supports O-RAN Service Models

- *E2SM-KPM*
- *E2SM-RC*

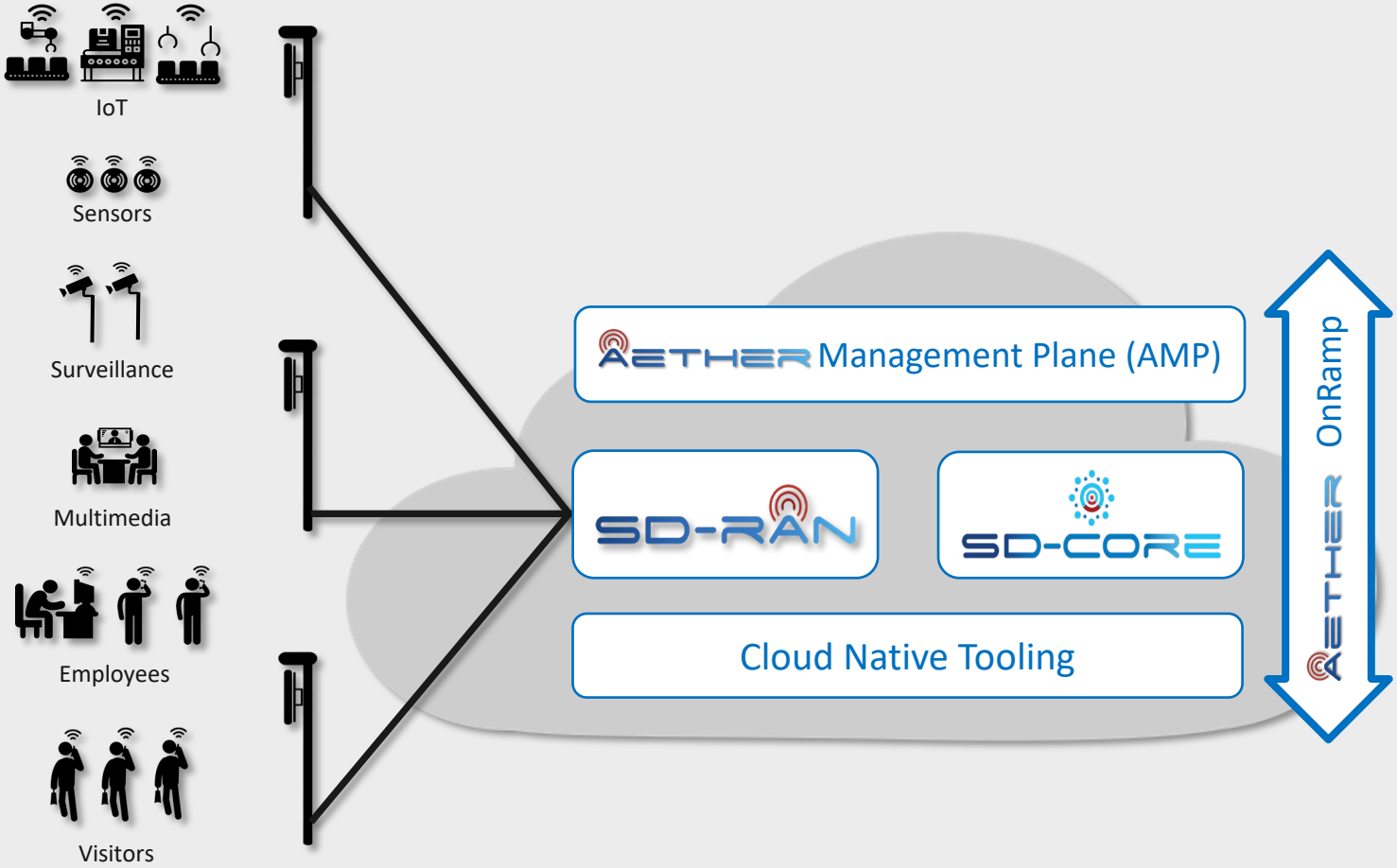
Connectivity-as-a-Service API



Runtime Control



Lifecycle Management

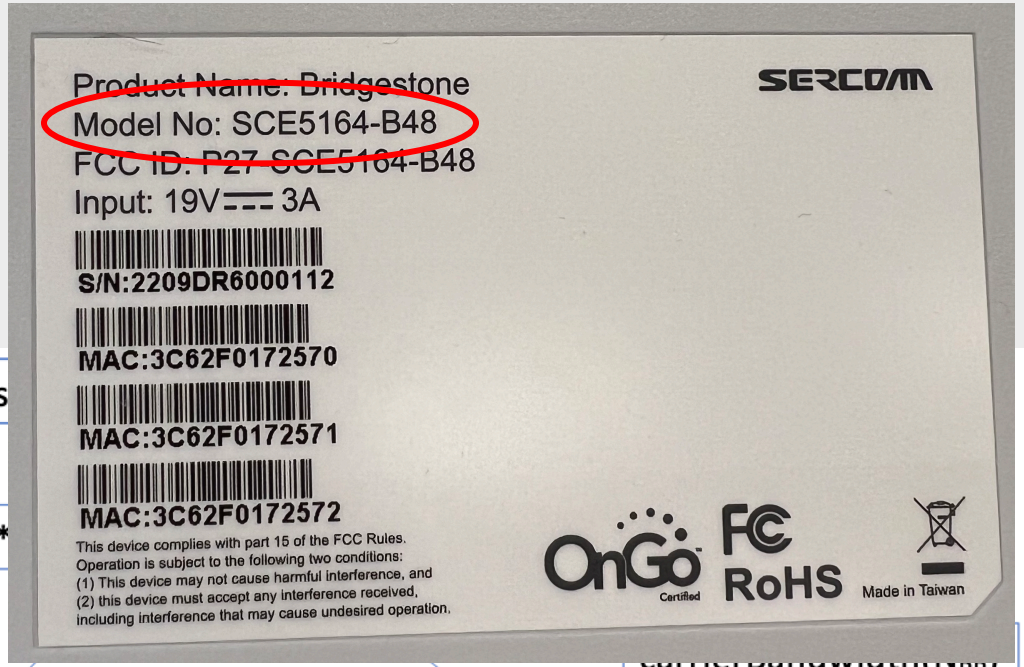


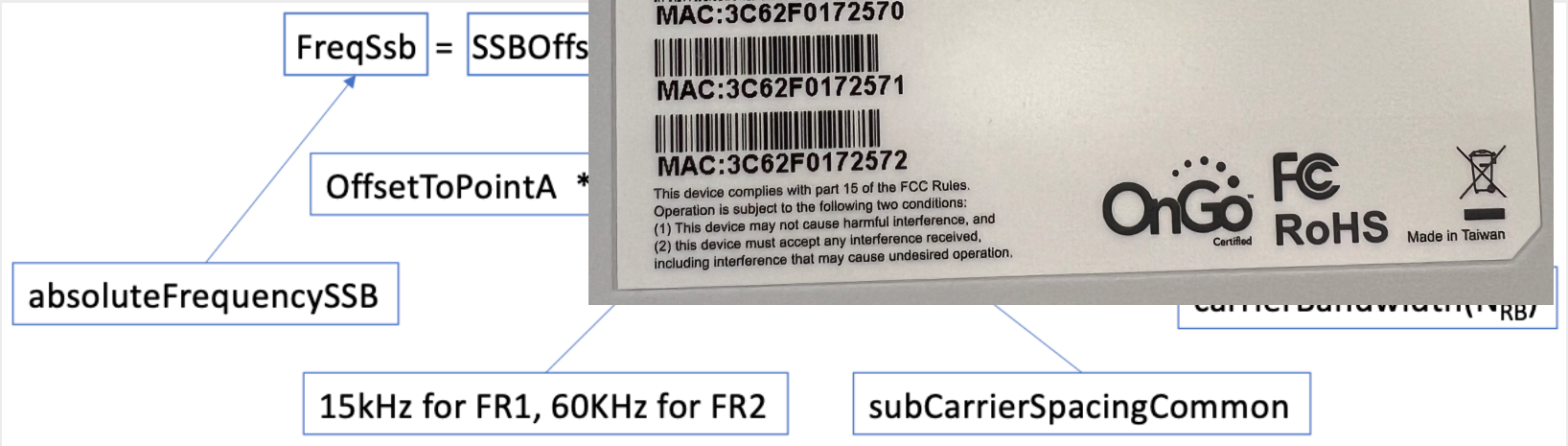
Configuration Challenge

SD-Core Helm Chart

- Control Plane (755 loc)
- User Plane (136 loc)

RF Configuration on gNB



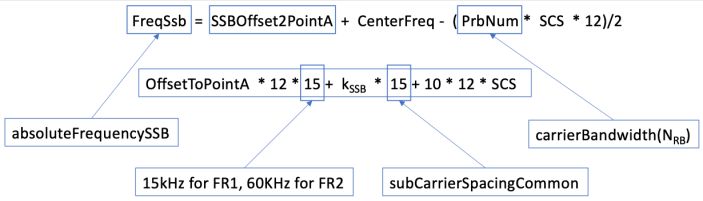


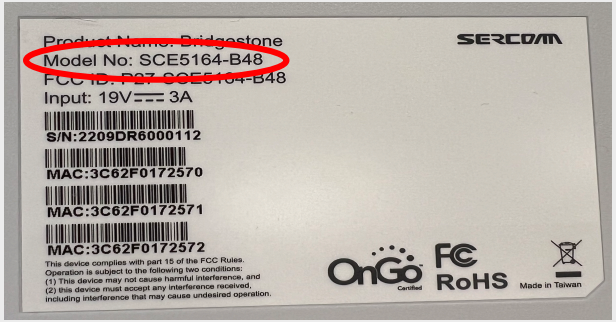
Configuration Challenge

SD-Core Helm Chart

- Control Plane (755 loc)
- User Plane (136 loc)

RF Configuration on gNB





Configure gNB

- Set RF parameters (band compatible with UEs)
- Define routes to the AMF & UPF
- Specify PLMN & Keys

Configure Core

- Specify PLMN & Keys
- Register a set of IMSIs
- Specify APN

Configure SIM Cards (USIM)

- Specify IMSI & Keys
- Enable Services expected from the Core (~200 loc)

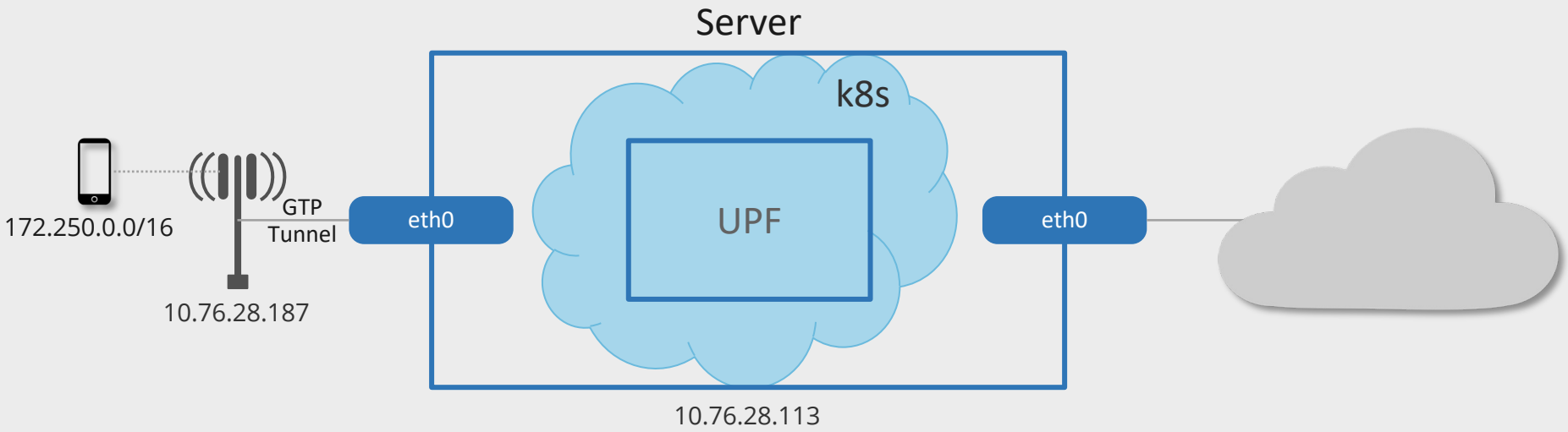
Configure UEs

- Specify APN

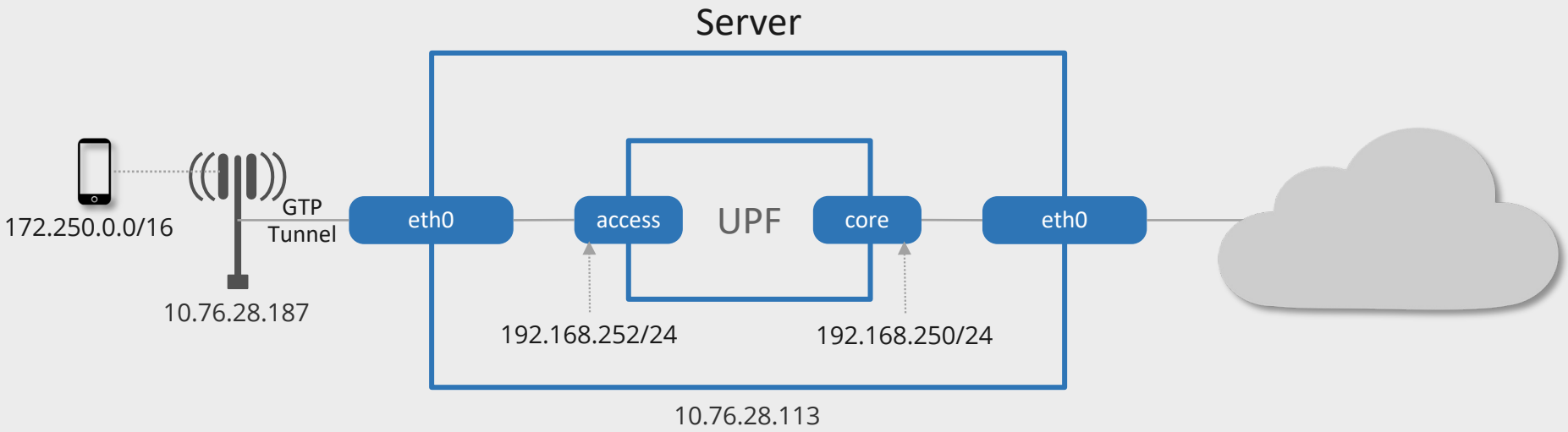
Configuration Challenge

ICCID: 8988211000000849383
IMSI: 001010123456789
...
USIM Service Table:
beff9f9de73e0408000070330000002601000000
- Service 2 - Fixed Dialing Numbers (FDN)
- Service 3 - Extension 2
- Service 4 - Service Dialing Numbers (SDN)
- Service 5 - Extension3
- Service 6 - Barred Dialing Numbers (BDN)
- Service 8 - Outgoing Call Information (OCI and OCT)
- Service 9 - Incoming Call Information (ICI and ICT)
- Service 10 - Short Message Storage (SMS)
- Service 11 - Short Message Status Reports (SMSR)
- Service 12 - Short Message Service Parameters (SMSP)
- Service 13 - Advice of Charge (AoC)
- Service 14 - Capability Configuration Parameters 2 (CCP2)
- Service 15 - Cell Broadcast Message Identifier
- Service 16 - Cell Broadcast Message Identifier Ranges
- Service 17 - Group Identifier Level 1
- Service 18 - Group Identifier Level 2
- Service 19 - Service Provider Name
- Service 20 - User controlled PLMN selector Access Technology
- Service 21 - MSISDN
- Service 24 - Multi-Level Precedence and Pre-emption Service
- Service 25 - Automatic Answer for eMLPP
- Service 27 - GSM Access
- Service 28 - Data download via SMS-PP
- Service 29 - Data download via SMS-CB
- Service 32 - RUN AT COMMAND command
- Service 33 - shall be set to 1
- Service 34 - Enabled Services Table
- Service 35 - APN Control List (ACL)
- Service 38 - GSM security context
- Service 39 - CPBCCH Information
- Service 40 - Investigation Scan
- Service 42 - Operator PLMN selector Access Technology
- Service 43 - HPLMN selector with Access Technology
- Service 44 - Extension 5
- Service 45 - PLMN Network Name
- Service 46 - Operator PLMN List
- Service 51 - Service Provider Display Information
- Service 60 - User Controlled PLMN selector for I-WLAN access
- Service 85 - EPS Mobility Management Information
- Service 86 - Allowed CSG Lists and corresponding indications
- Service 87 - Call control on EPS PDN connection by USIM
- Service 89 - eCall Data
- Service 90 - Operator CSG Lists and corresponding indications
- Service 93 - Communication Control for IMS by USIM
- Service 94 - Extended Terminal Applications
- Service 122 - 5GS Mobility Management Information
- Service 123 - 5G Security Parameters
- Service 126 - UAC Access Identities support
- Service 129 - 5GS Operator PLMN List

Deployment Challenge

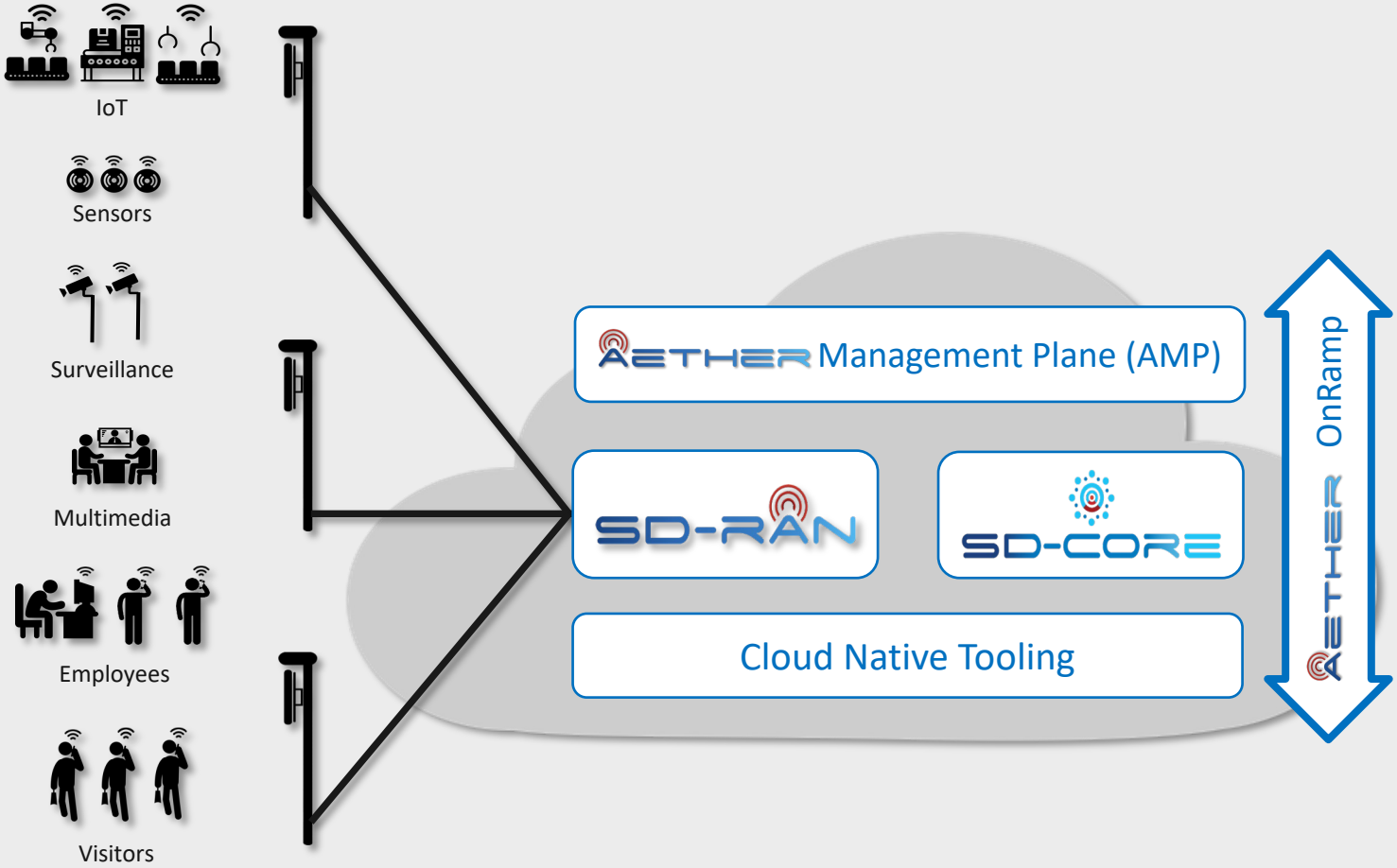


Deployment Challenge



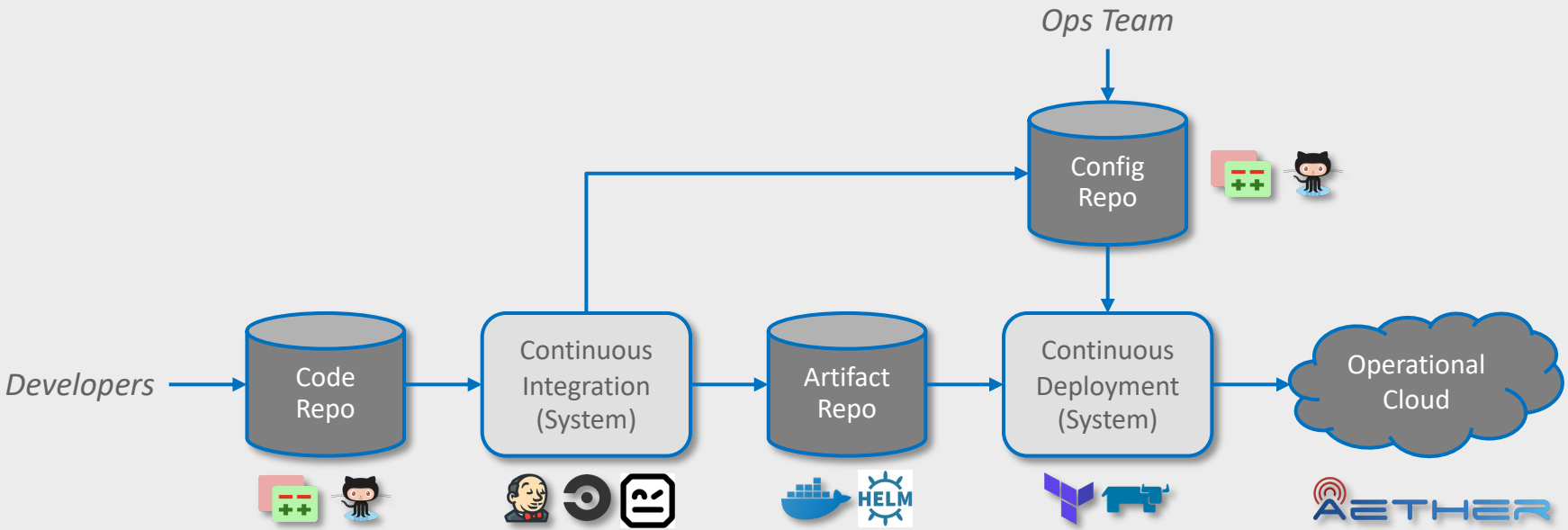

```
$ sudo tcpdump -i eth0 port 2152 -w n3-outside.pcap
$ sudo tcpdump -i access port 2152 -w n3-inside.pcap
$ sudo tcpdump -i core net 172.250.0.0/16 -w n6-inside.pcap
$ sudo tcpdump -i eth0 net 172.250.0.0/16 -w n6-outside.pcap
```

Lifecycle Management



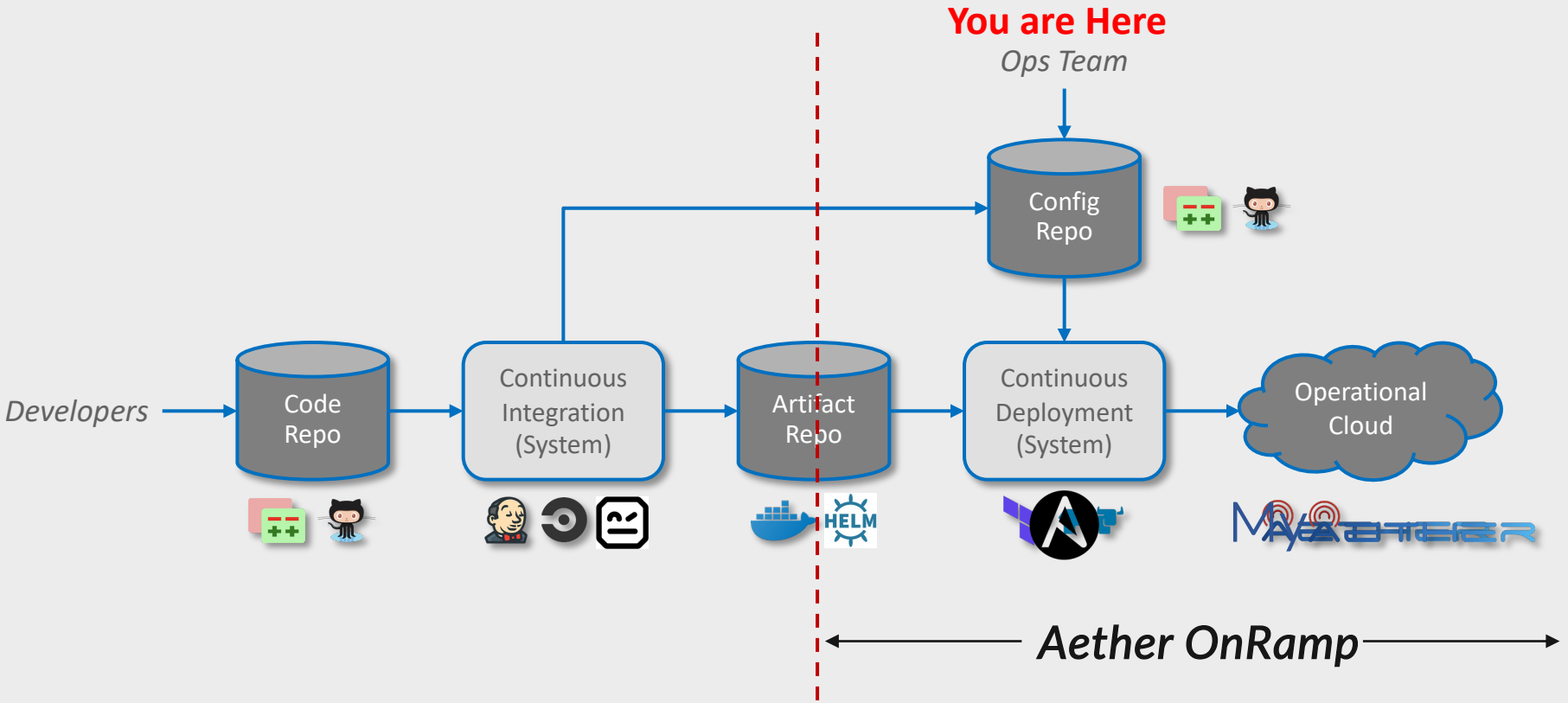
LIFECYCLE MANAGEMENT

(Continuous Integration / Continuous Deployment)



LIFECYCLE MANAGEMENT

(Continuous Integration / Continuous Deployment)



AETHER ONRAMP

Transitioning Aether: Managed Service → Deployable Platform

- *Includes tooling needed to run as a managed cloud service*
- *Goal is to help users "own" the configuration*
- *Supports Education, Research, Field Trials, Commercial Deployments*

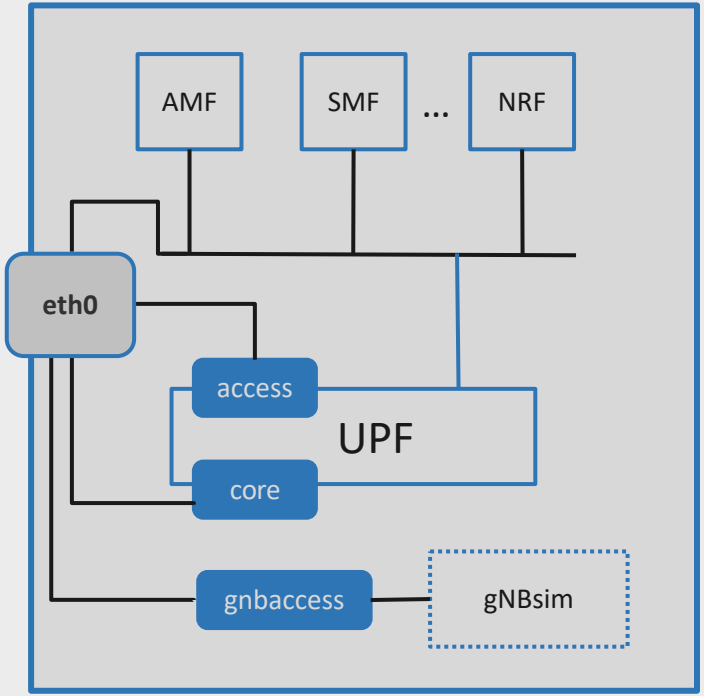
Designed to scale up for different target environments & feature sets

- *Single Server / Emulated or Physical gNBs*
- *Single Site Cluster / Emulated or Physical gNBs*
- *Single Site Cluster / SD-RAN based RAN*
- *Multi-Site Hybrid Cloud*

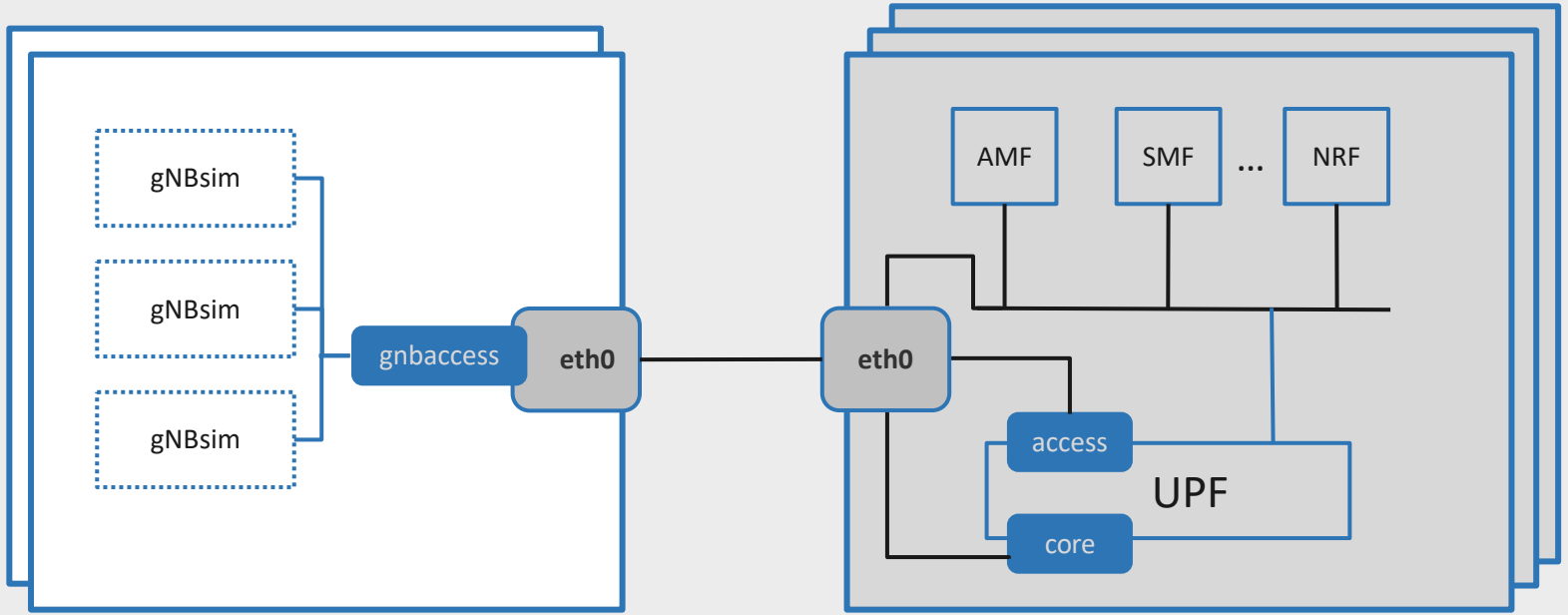
A *blueprint* defines each configuration package

- *From "QuickStart" to get started on a single Server/VM*
- *To "Cluster with Physical gNBs" for field trials*

QuickStart Blueprint

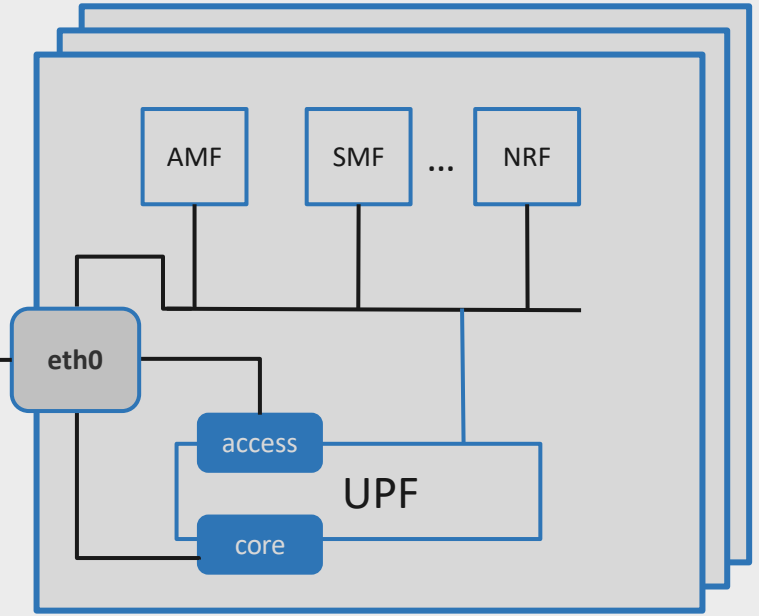


Scalable Emulated RAN Blueprint

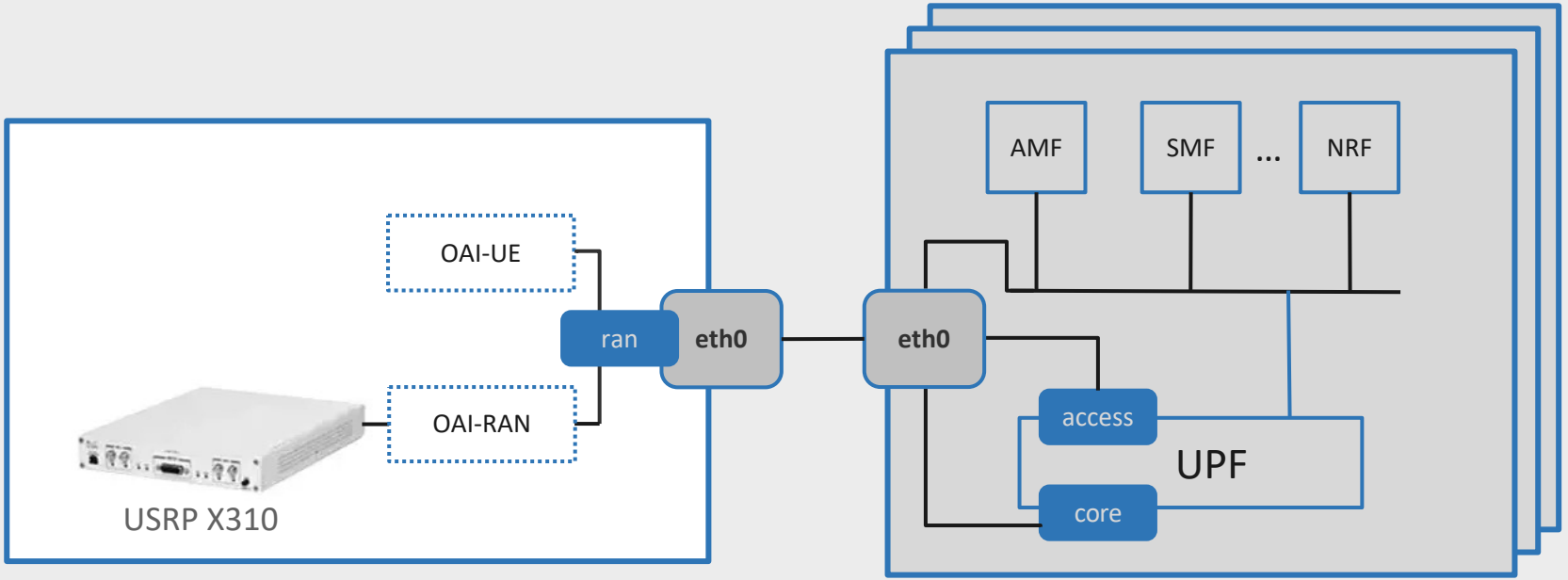


PHYSICAL RAN BLUEPRINT

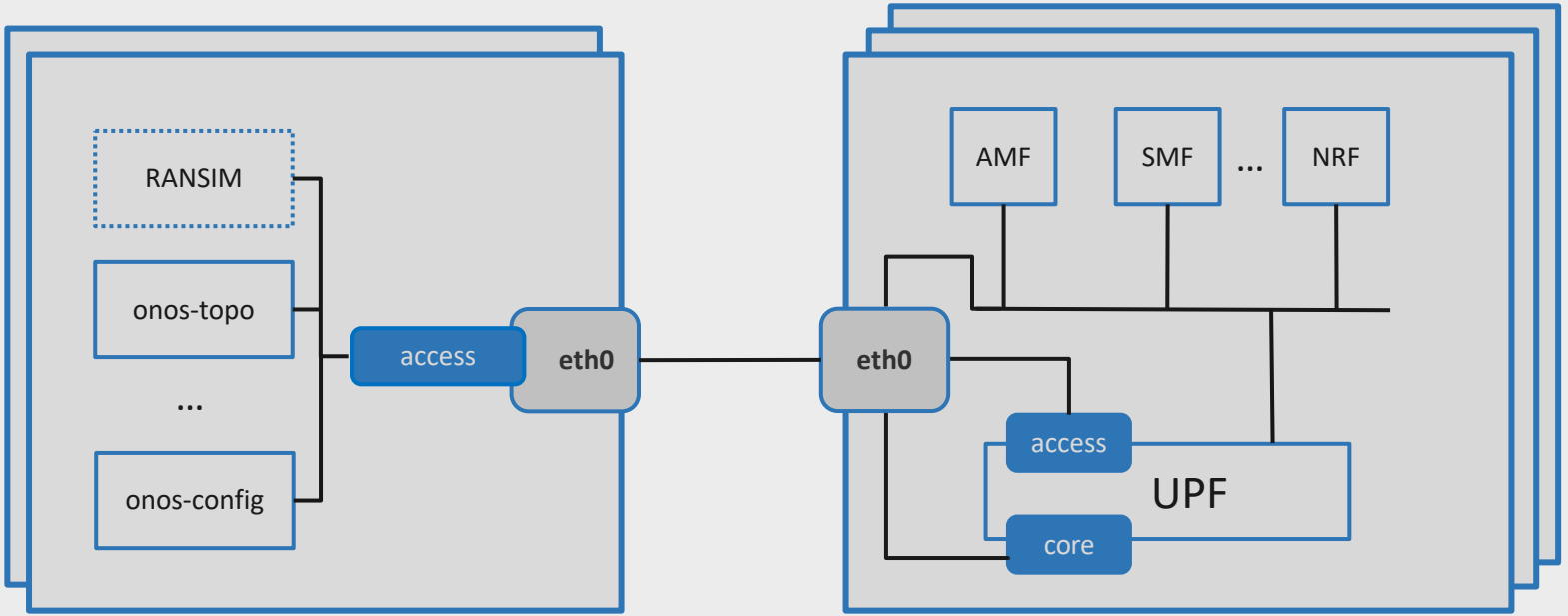
MOSO CANOPY 5G
INDOOR SMALL CELL



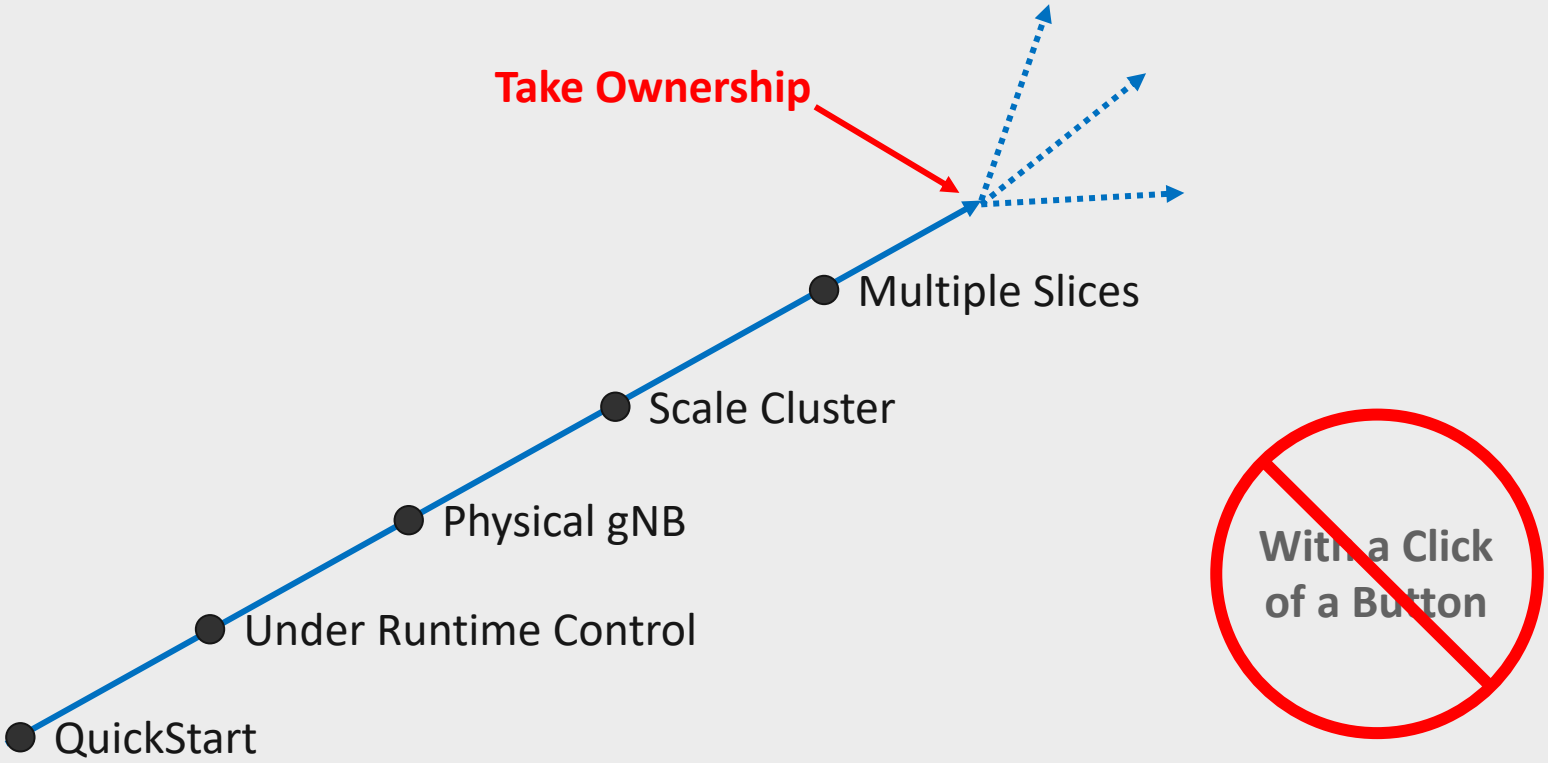
OAI RAN Blueprint



SD-RAN Blueprint



OnRamp: Incremental Complexity



Layered Configuration State

Blueprint Level Configuration Files

- Variables: vars/main-gNB.yml (68 loc)
- Inventory: hosts.ini (13 loc)

Per-Blueprint Override Files

- Physical gNB: radio-5g-values.yaml (225 loc)

Developer-Provided Helm Charts

- From Earlier Slide (755+136 loc)

TAKEAWAYS

Network operations (management) is a substantial barrier to adoption

- Unusually so for 5G

Hands-on experience requires at least some operational capability

- Operating a system exposes the next research challenge
- Contributing back is critical to adoption and impact

There are limits to automation

- Support a fixed set of pre-defined scenarios
- Key is empowering users to take ownership
- Ownership requires education / training / knowhow / …

TAKEAWAYS

Reduces to a state management problem, with multiple timeframes/stakeholders

- Development Time → Engineers
- Deployment Time → Operators
- Runtime Control → Users

More Information

Web Site

- *https://aetherproject.org*

Guide

- *https://docs.aetherproject.org*

Wiki

- *https://wiki.aetherproject.org*

GitHub

- *OnRamp: https://github.com/opennetworking*
- *SD-Core: https://github.com/omec-project*
- *SD-RAN: https://github.com/onosproject*

Educational Material

- *http://systemsapproach.org/books*