5G Network Slicing

Optimized with Red Hat Technology

Application of Red Hat Infrastructure & Middleware

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9 May, 2021

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Definitions & Assumptions

- ***Critical Functions*** **are implemented on "Carrier Grade" Cloud infrastructure (*CGCI*)**
  - "Cloud Infrastructure" such as OpenShift, Kubernetes K8s
  - Multi-Access Edge Cloud (***MEC***)
  - RAN Intelligent Controller (***RIC***)
  - Virtual RAN (***vRAN***)
  - (v/c)NFs on Virtual Machines (VMs) or Containers

- **A *RIC* (specified by the ORAN-Alliance) is integrated with the MEC and vRAN**
  - The RIC contains micro-services (xApps, rApps) and AI/ML components for RAN Optimization and Management
  - RAN Optimization occurs per service slice or in the aggregate

- ***"Service Slices"*** **are defined by the Mobile Network Operator (MNO, MVNO) or Customer (Enterprise)**
  - The MEC contains Apps (micro-services) driven by MNO or Enterprise value-added use cases
  - Use Cases fall within URLLC, mMTC, eMBB categories

- **"*Orchestration*" functions include:**
  - VNF/CNF instantiation and stitching
  - App instantiation
  - Service chaining, configuration and stitching for NFs and other devices
  - RRU/BBU or O-RAN decomposed O-RU, O-DU, O-CU static and dynamic configuration
  - Transport instantiation and config (Front-Haul, Mid-H, Back-H, IP Core Xport)

Software Defined Networks
Network Resource Multiplexor

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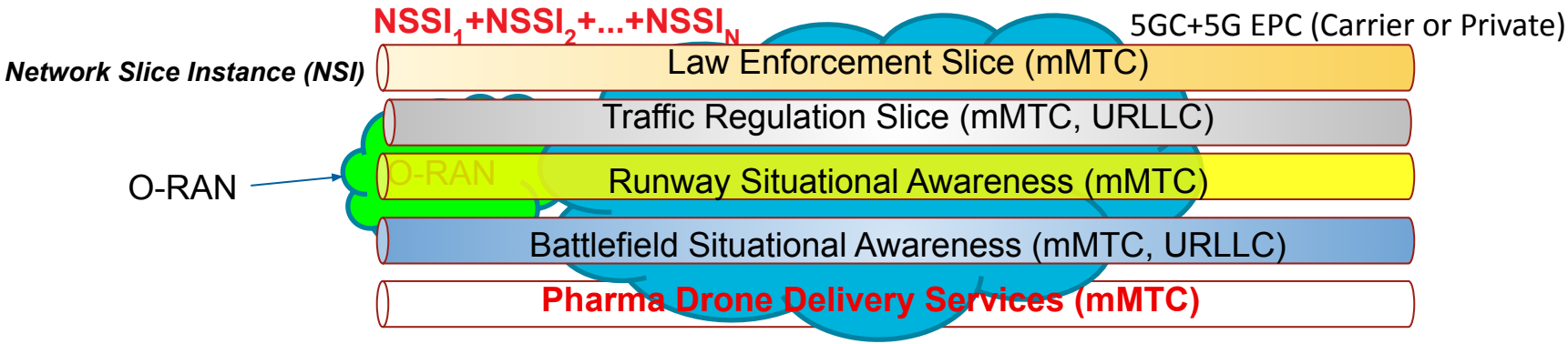
What is a “Network Slice” in 5G?

A software-defined (SDN) “overlay” on the network infrastructure (i.e., a VPN)

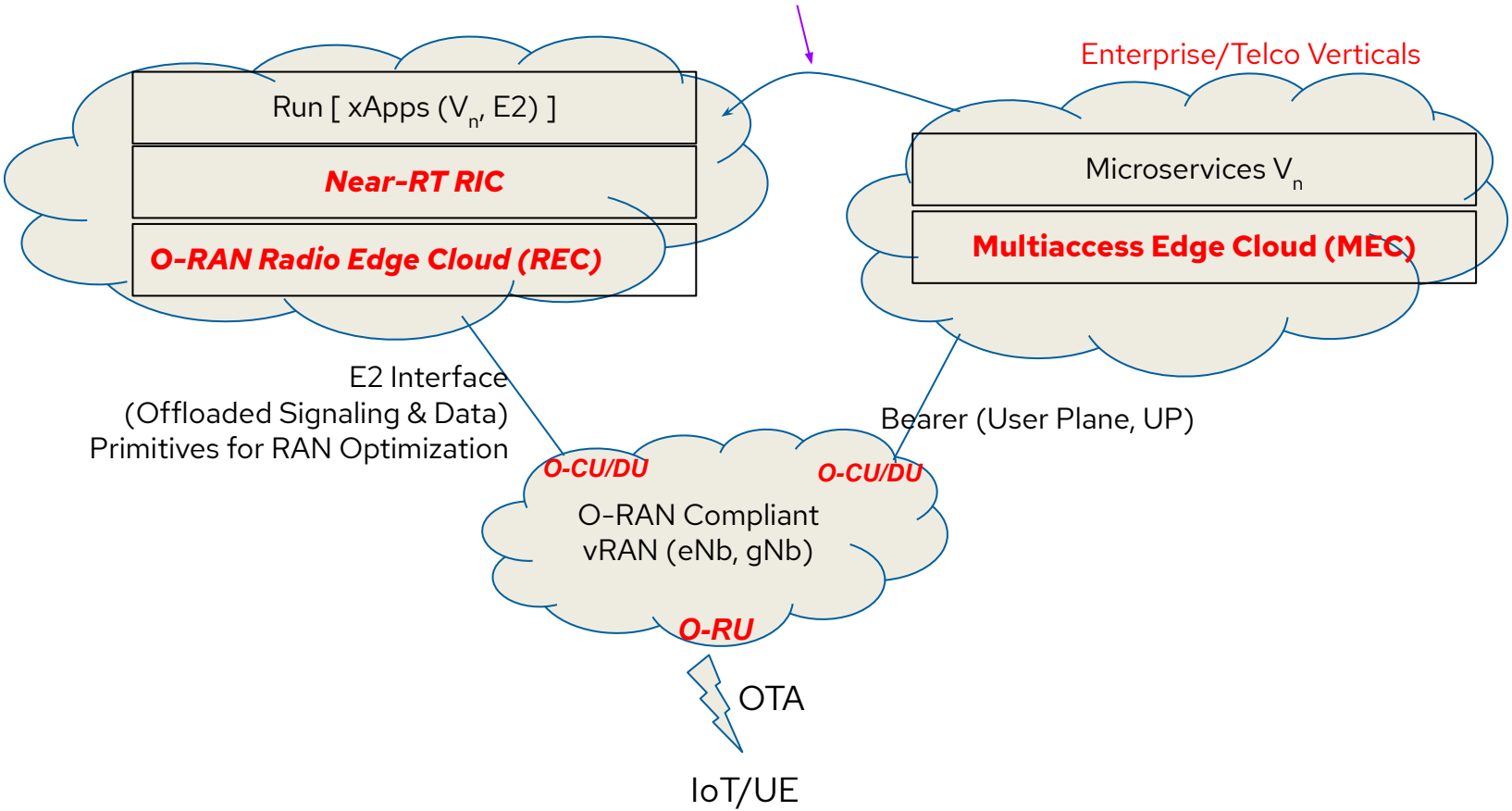
- An instance of a Network Slice per 3GPP is a “***Network Slice Instance***”, or NSI
- An NSI is constructed by combining subnets, referred to as Network Slice Subnet Instances (NSSI)
  - NSSI are Compute, Storage, & Network resources
    - E.g., Network Functions, Logical constructs, such as ports & links, microservices, apps
    - These are modeled via a “template” describing subnet attributes
- NSSI and NSI can be modeled and constructed via an Orchestration system (e.g., ONAP)

Each NSI focuses on particular use cases and has its own SLA/QoS/QoE

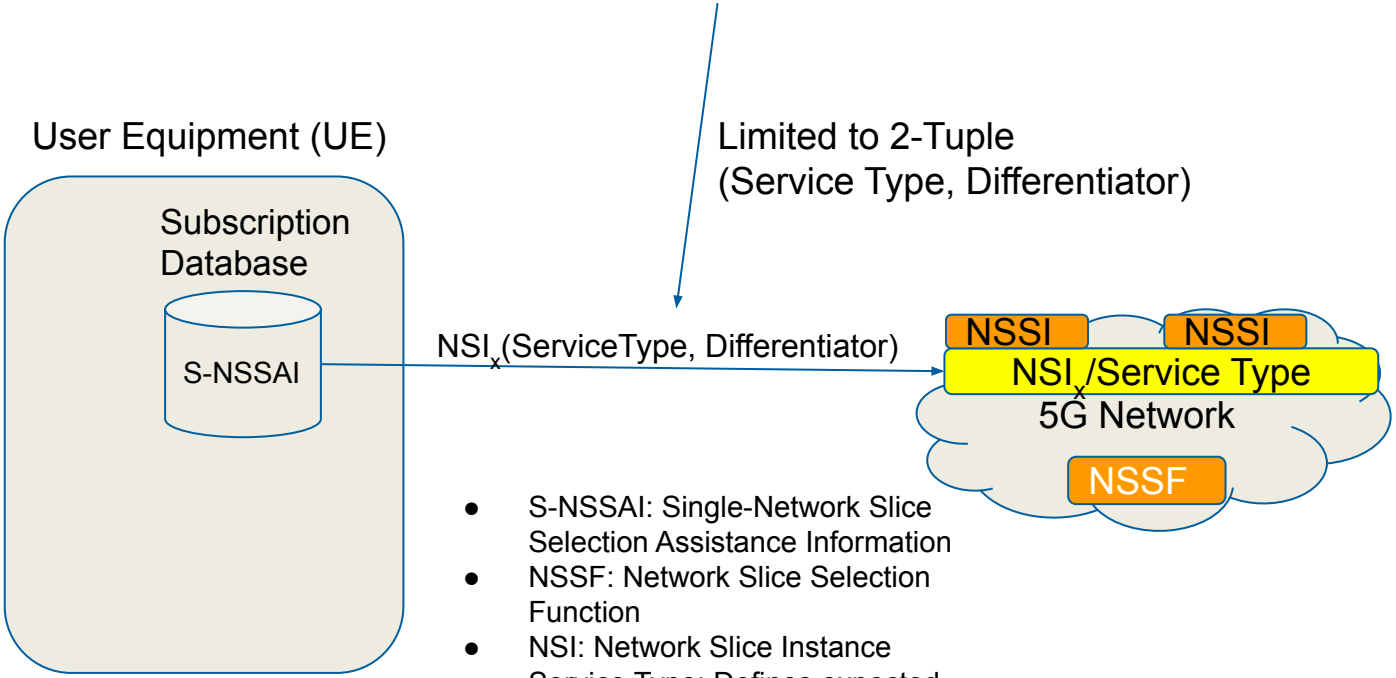
- **Example NSI:**
  - DoD – Enhanced battlefield situational awareness via equipment/personal IoT
  - Law Enforcement – City surveillance enhancement via multiple cameras, sensors, IoT worn by officers
  - Traffic Regulation and Policing
    - Change street lights based on actual traffic vs. TOD only
    - Improved throughput on highways via use of intelligent cars (Autonomous Vehicles)
  - FAA – Improved field of vision/situational awareness on runways



Enterprise Verticals Network Slice



Limited NSSI in 3GPP Network Slicing Spec

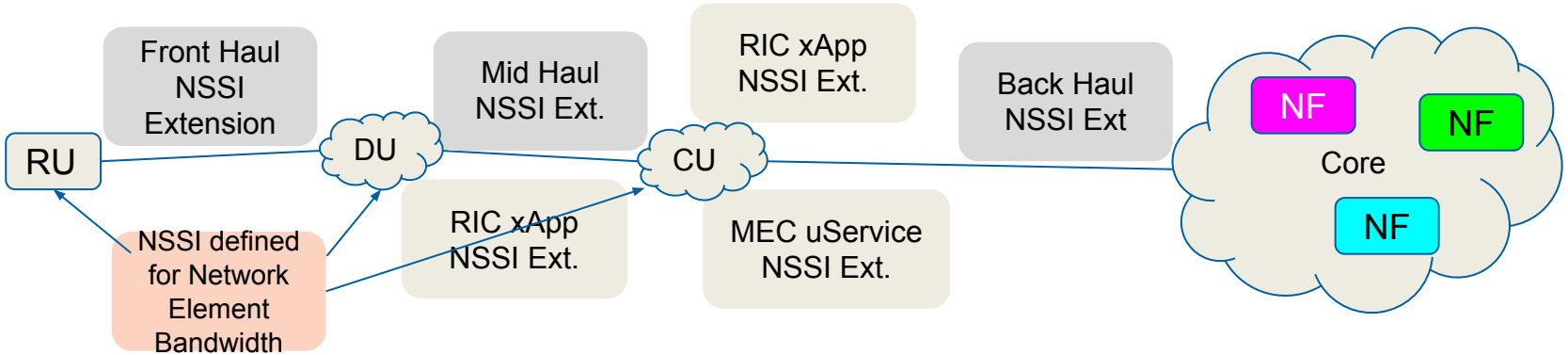


- S-NSSAI: Single-Network Slice Selection Assistance Information
- NSSF: Network Slice Selection Function
- NSI: Network Slice Instance
- Service Type: Defines expected network slice behavior, depending on its specific features and service(s)
  - eMBB, mMTC, URLLC
- ***Currently vendors & Telcos are using "Orchestration-based" slicing because of 3GPP limitation***

Network Slicing Extensions beyond 3GPP

NSSI Modeling for xApps, MEC Microservices, xHauls

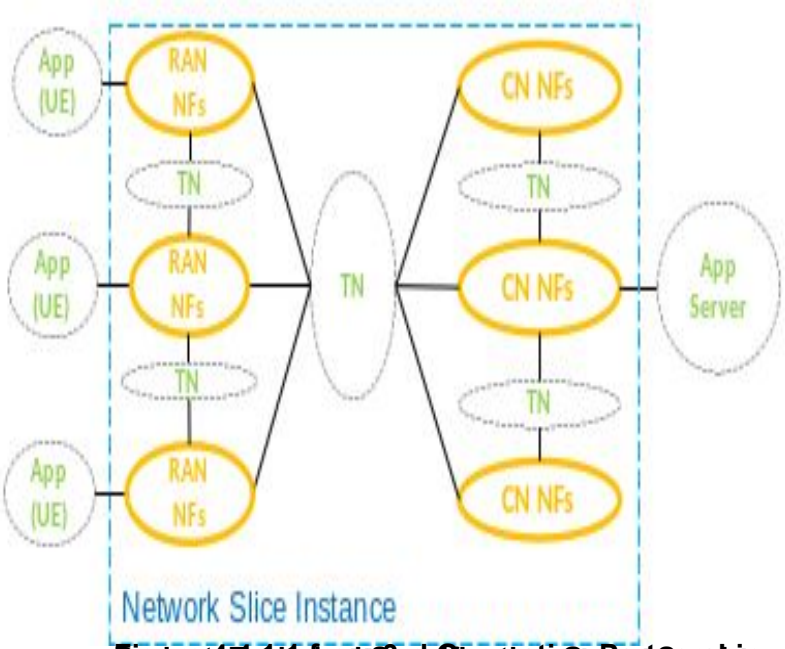
- Current 3GPP Specs for Slicing are Limited
  - NSI is currently a 2-Tuple (Service Type, Differentiator)
  - MNOs/MVNOs/Enterprises need to include “extensions”
    - NSI (Service Type, Differentiator, Extensions)
    - Extensions include xHaul bandwidth, MEC microservices, REC xApps
    - NSSI “templates” should allow for customization to include any network subnet
  - Early Network Slicing POCs are/were performed with “Orchestration-based” capability
    - NSSI for RAN, MEC, REC, Transport are modeled and “pushed” to the network



NSI Component Breakdown

An NSI is an SDN with its own service offerings built from NSSI and a particular Service Profile

- NSI = [(NSSI1 || NSSI2 || ….. || NSSIn), Service Profile (CoS[], QoE[], SLA[])]
- Service Type/Profile ()
  - A unique set of services independent of other NSI and the physical network
  - Custom CoS/QoE, Performance and reliability SLAs
  - Requires its own set of FCAPS in addition to the physical network FCAPS
  - Realized via Slice as a Service (SlaaS), Slice as Infrastructure, or defined via a central OSS/Orchestration system
  - Typically managed by an MVNO (Mobile Virtual Network Operator)



NSSI Examples

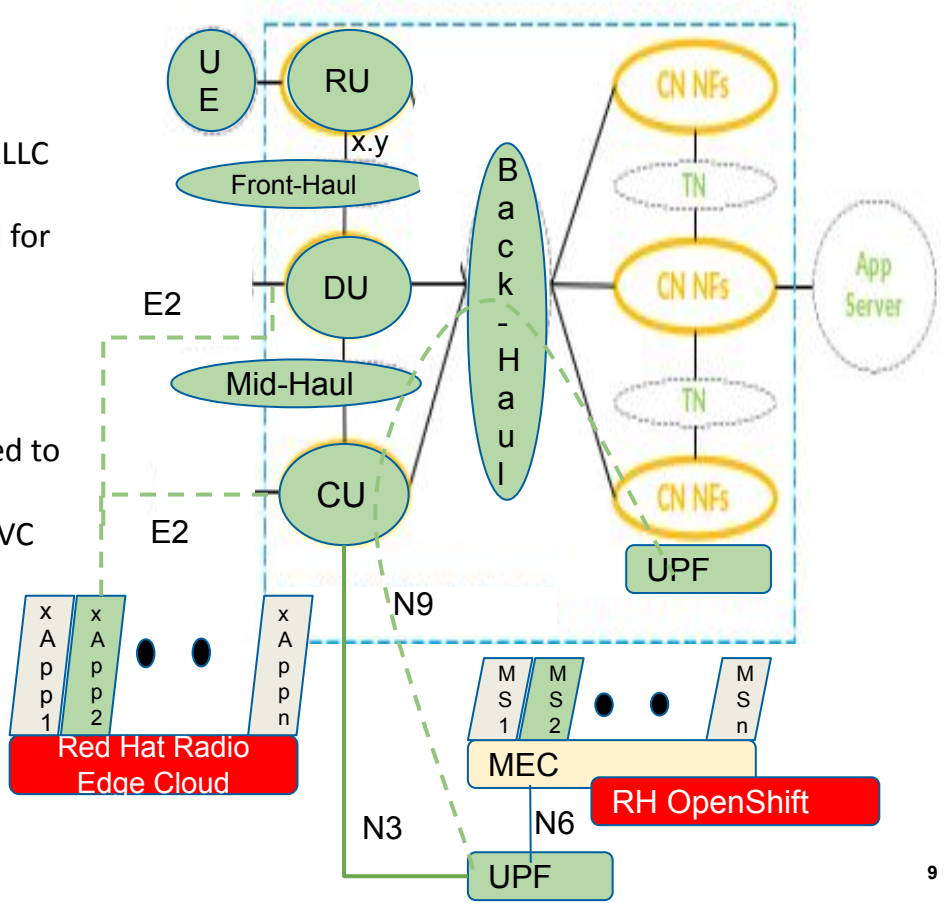
Legend: Network Slice NSSI

Reserved resources from the RAN, vRAN, 5GC, EPC

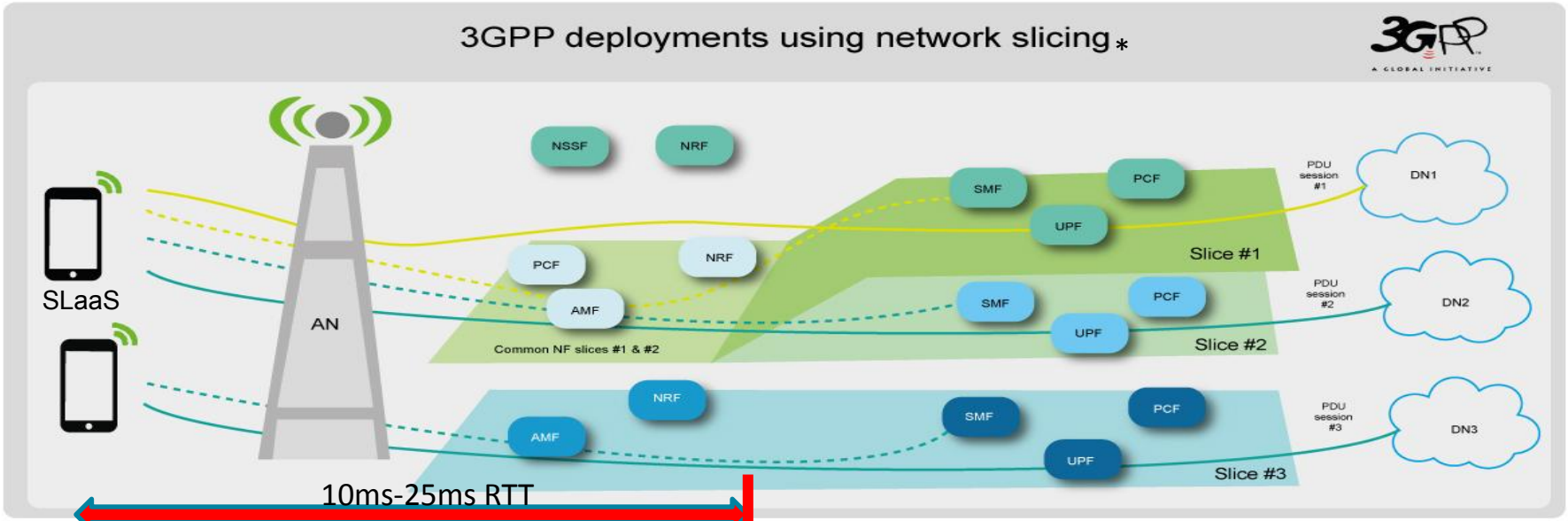
- Examples:
  - A unique UPF instance at an edge location supporting a particular NSI's data plane for URLLC services
  - vRAN logical ports (e.g., x.y, VLAN ID) reserved for an NSI over which that NSI's services flow

Extensions defined by the carrier

- Examples:
  - Backhaul Ethernet Virtual Circuit (EVC) assigned to a particular NSI
    - E.g., a Verizon IEN EVC, an AT&T IPAG EVC
  - A specific MEC microservice used to provide a particular NSI's service(s)
  - A specific RIC xApp designated to provide a particular RAN optimization for a given NSI's service(s)



Telco/MNO E2E View of Network Slicing



*Mademann, Frank. (2017). 3GPP System architecture milestone of 5G Phase 1 is achieved", https://www.grandmetric.com/2018/03/02/5g-core-network-functions/

Network Slicing Products

- ***Orchestration-Based Slicing Products***
  - Ericsson
  - ZTE
  - Viavi
  - Nokia/Cloudstreet Dynamic Profile Controller (NPC)
  - Ciena Blue Planet
  -

*Depending on the carrier, some assets may be owned and/or managed by other entities based on a prior business arrangement, such as RAN Sharing.

Network Slicing with Red Hat Technologies

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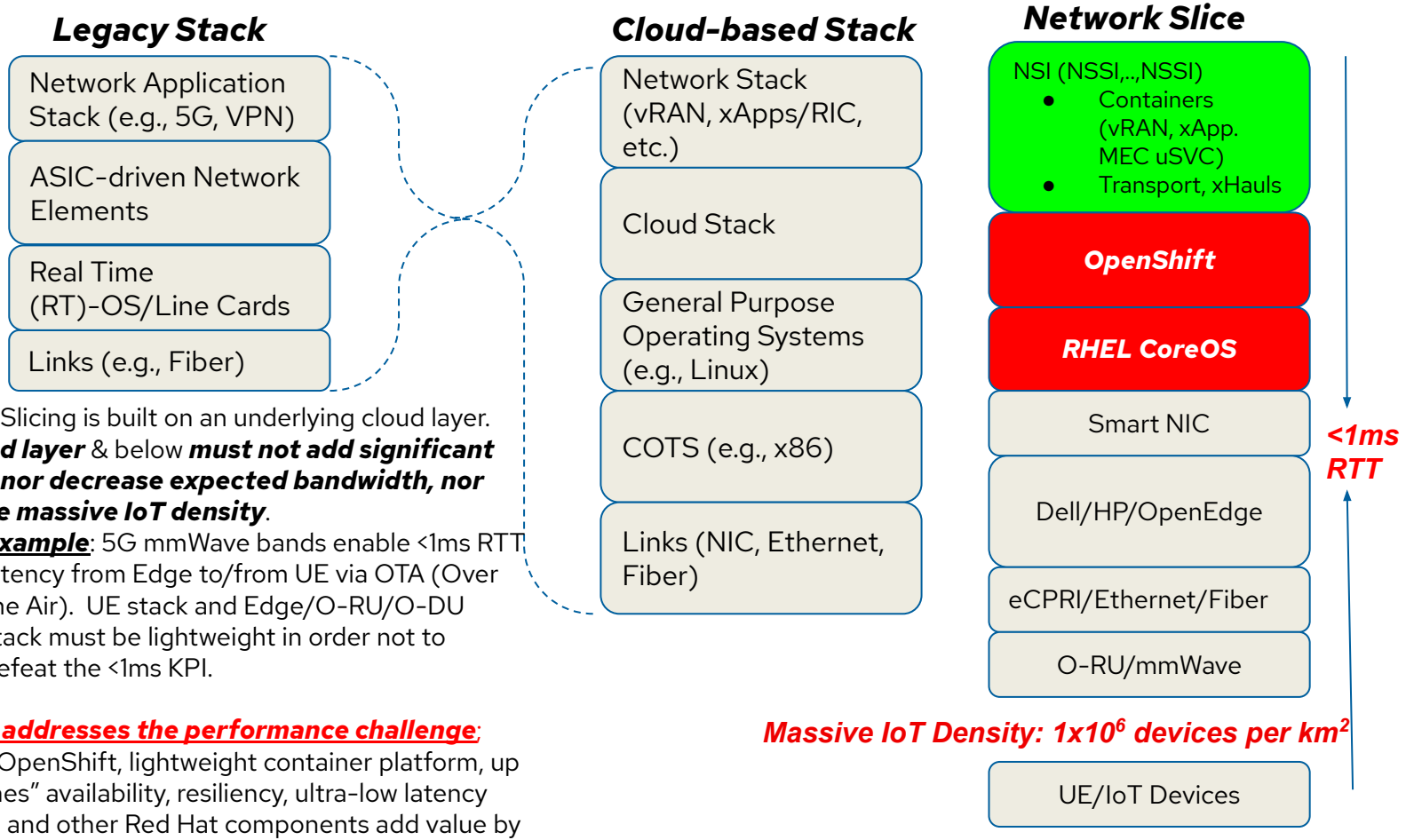
Performance Challenge: "*5G Slice on Cloud*"

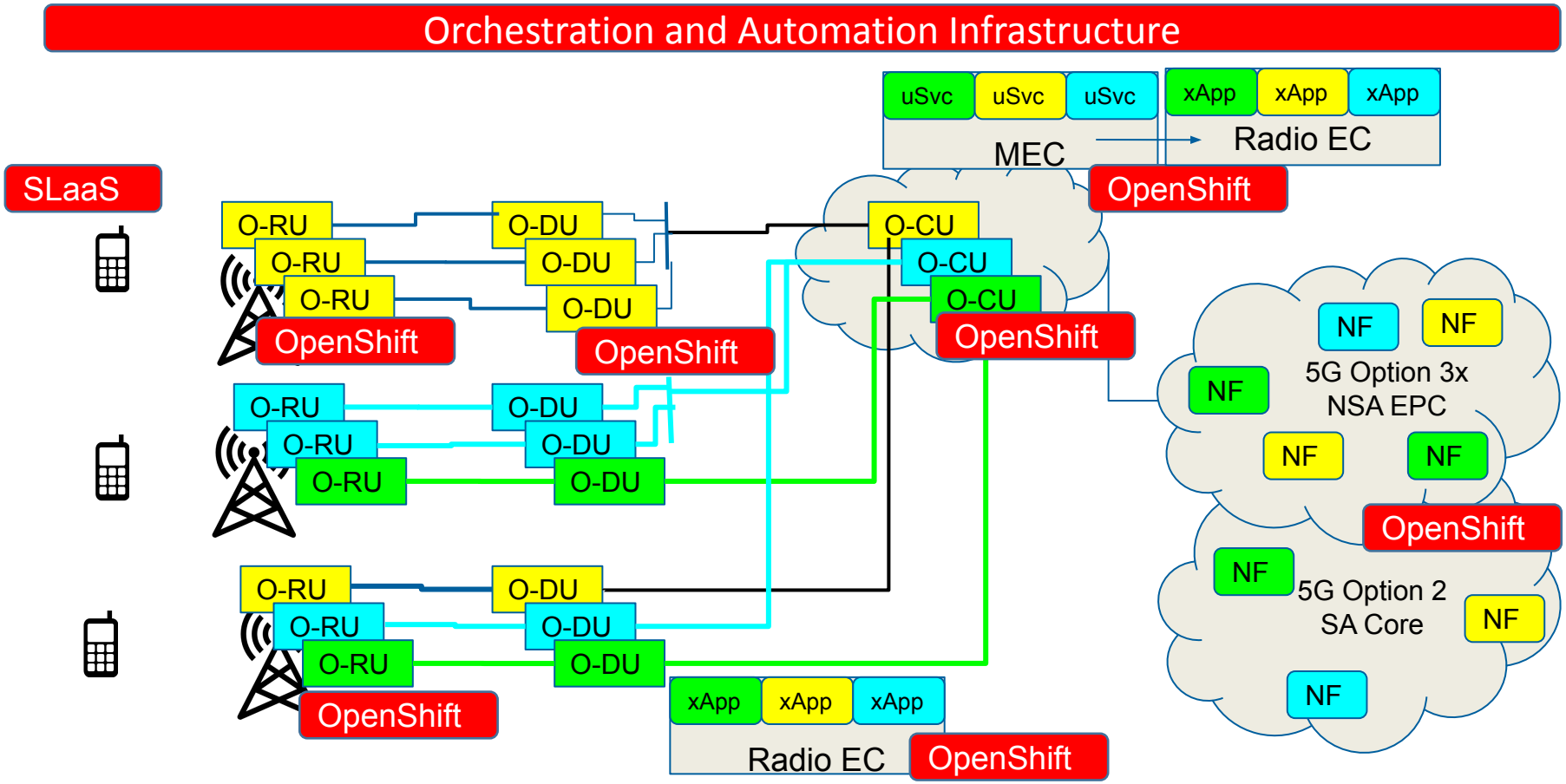


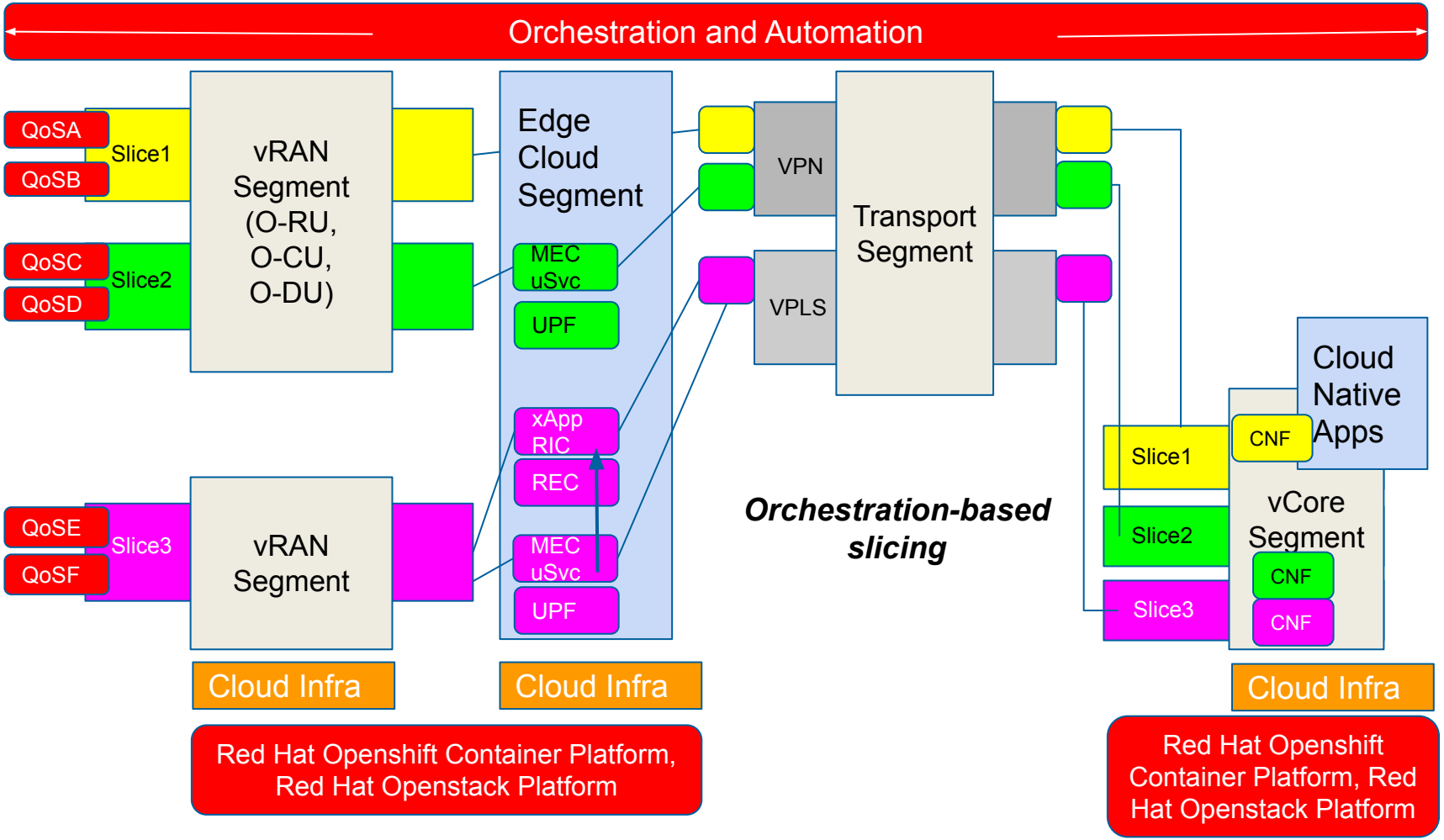
- Network Slicing is built on an underlying cloud layer.
- The ***cloud layer*** & below ***must not add significant latency, nor decrease expected bandwidth, nor decrease massive IoT density***.
  - ***Example***: 5G mmWave bands enable <1ms RTT latency from Edge to/from UE via OTA (Over the Air). UE stack and Edge/O-RU/O-DU stack must be lightweight in order not to defeat the <1ms KPI.

- ***Red Hat addresses the performance challenge***; Red Hat OpenShift, lightweight container platform, up to "6-Nines" availability, resiliency, ultra-low latency data bus, and other Red Hat components add value by enabling & preserving anticipated 5G KPIs.

Monetization via Network Resource Multiplexing

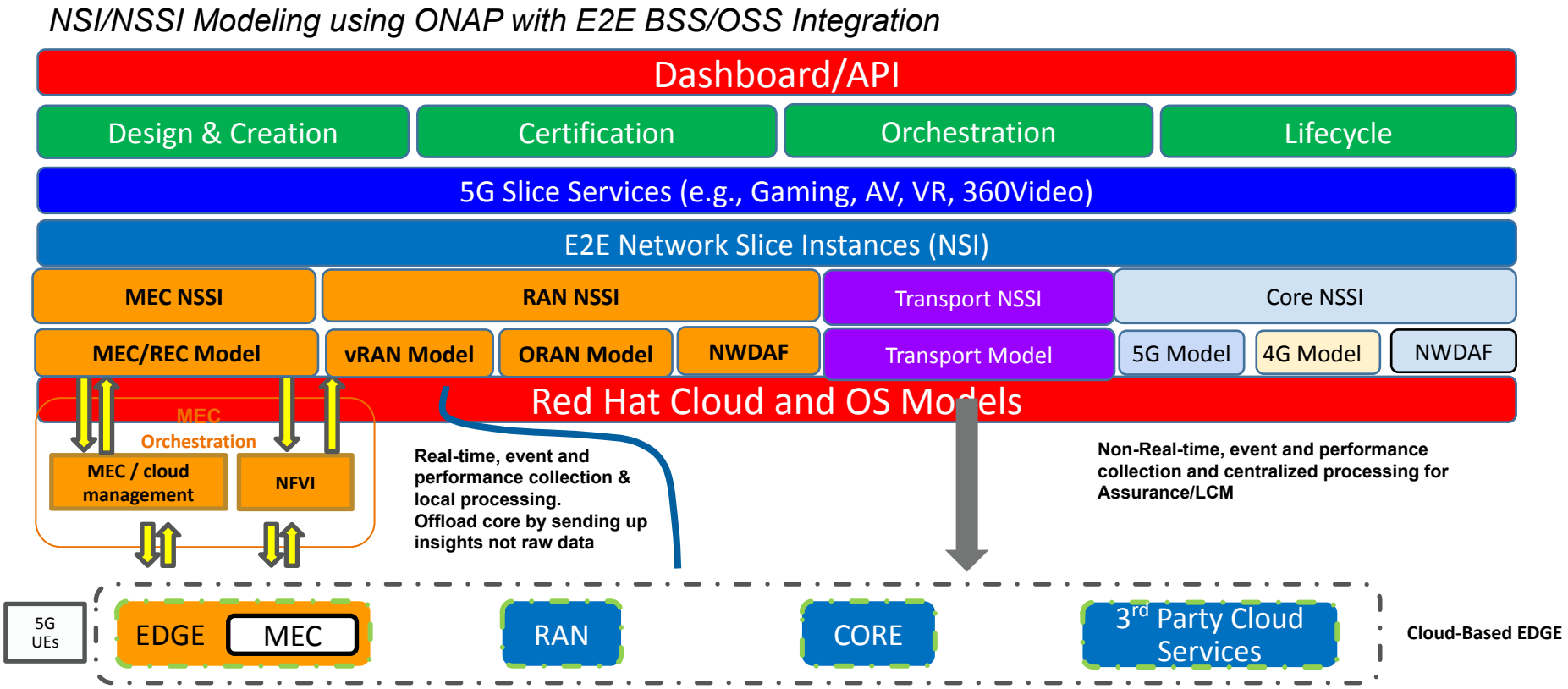
Urban/Suburban/Local Data Center | Regional Data Center | National Data Center





CNF: Core Network Function UPF: User Plane Function VPLS: Virtual Private LAN Service

Proposed ONAP-Based NSI/NSSI Software Stack



Network Slice Management
MNO, MVNO, Enterprise

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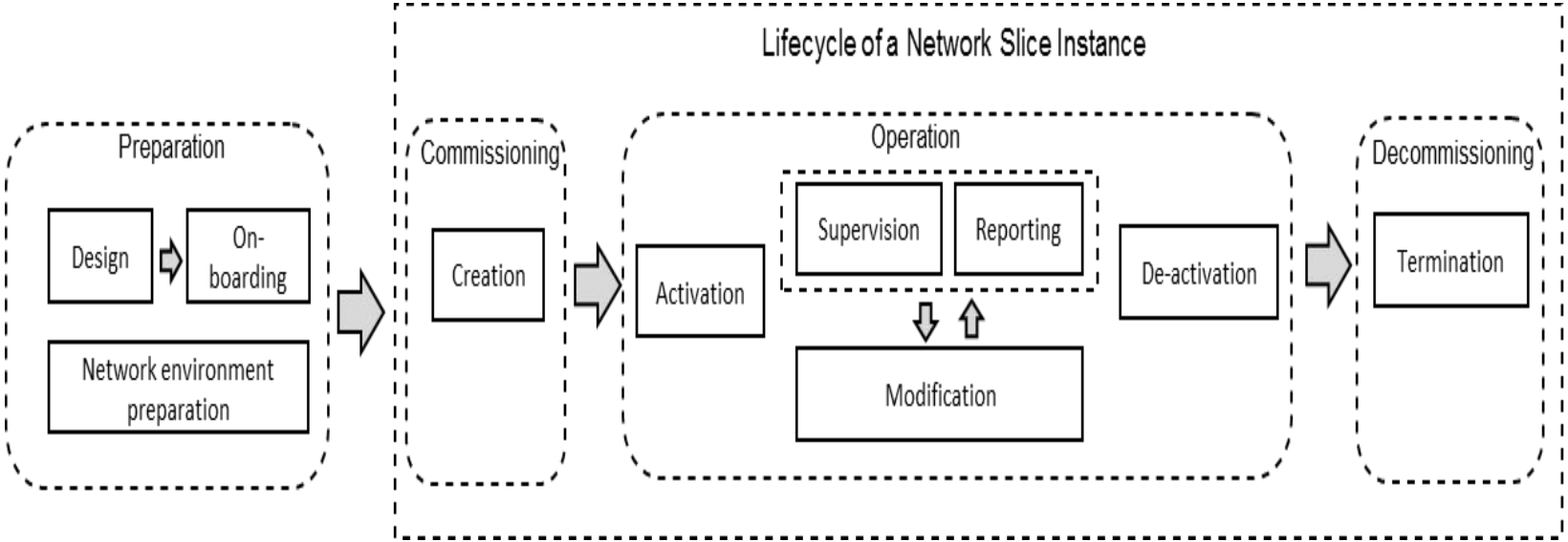
NSI Phases from TR 28530 Release 15 Network Slicing



Mobile Network Operators and Network Slice Operators

- ***Mobile Network Operators (MNO)***
  - "Typically" operates and manages all network assets (sw + hw)*
  - Typically has allocation rights for all network assets*
  - "All network assets" in reality means the "network infrastructure as a whole", prior to any NSI (VPN) definitions
  - The allocation of NSI resources are at the discretion of the MNO

- A **"Mobile Virtual Network Operator (MVNO)"** or **Enterprise** would typically manage an NSI
  - An enterprise that "purchases" or "leases" a "slice contract" from an MNO is an MVNO
  - An MVNO "typically" operates and manages the virtual entities comprising the NSI*
  - The design of a particular NSI depends on the business model between an MNO and MVNO (or Enterprise)
    - An MVNO would negotiate with the MNO for the set of services and the Classes of Service (CoS) needed for their NSI(s)
    - Generally, higher CoS for an NSI dictates the allocation of more resources by the MNO
    - Depending on the business model/agreement, the MVNO may take on operation and management of some physical assets (e.g., Far Edge uCPE/Whitebox)

*Depending on the carrier, some assets may be owned and/or managed by other entities based on a prior business arrangement, such as RAN Sharing.

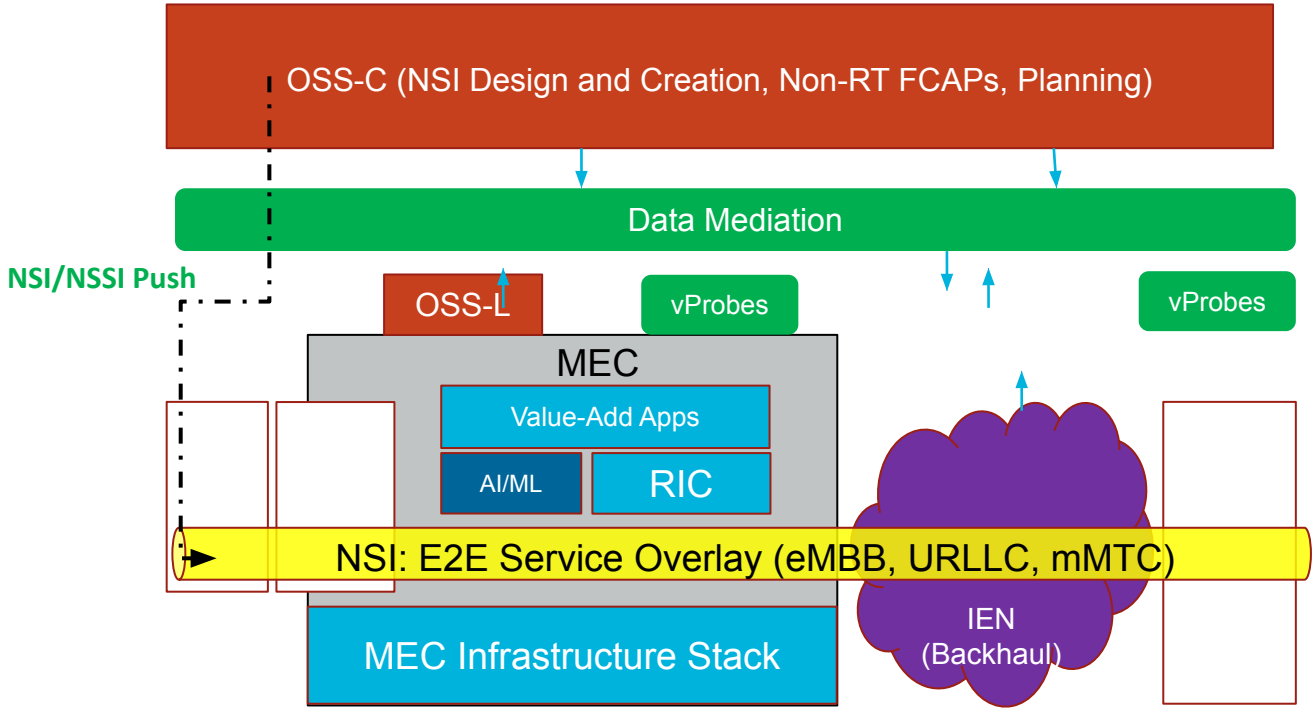
Federated Management Model

- **"Federated" OSS & BSS functions**
  - OSS-Central (OSS-C) focused on Non-RT FCAPS (>200ms)*
    - Legacy functions, such as Billing, Cap Mgmnt
    - NSI design, NSSI modeling, NSI orchestration
  - OSS-Local (OSS-L, distributed)
    - Focuses on data mediation
      - offload/aggregation, insight generation toward OSS-C
    - Low-latency closed-loop control
    - Other latency sensitive operations
      - Operations requiring RT (<=20ms) or Near-RT (<=100-200ms) latency (Edge or Far-Edge)*
        - E.g., Video Rendering
- **Management Demarcation**
  - MNO and MVNOs (Enterprises) will do parts of OSS-C and OSS-L
  - Examples:
    - MVNOs may have their own Billing systems for an NSI's services
    - MNO will bill MVNOs based on the business model for NSI allocations
    - MVNOs may provide video rendering services for their "Gaming" NSI

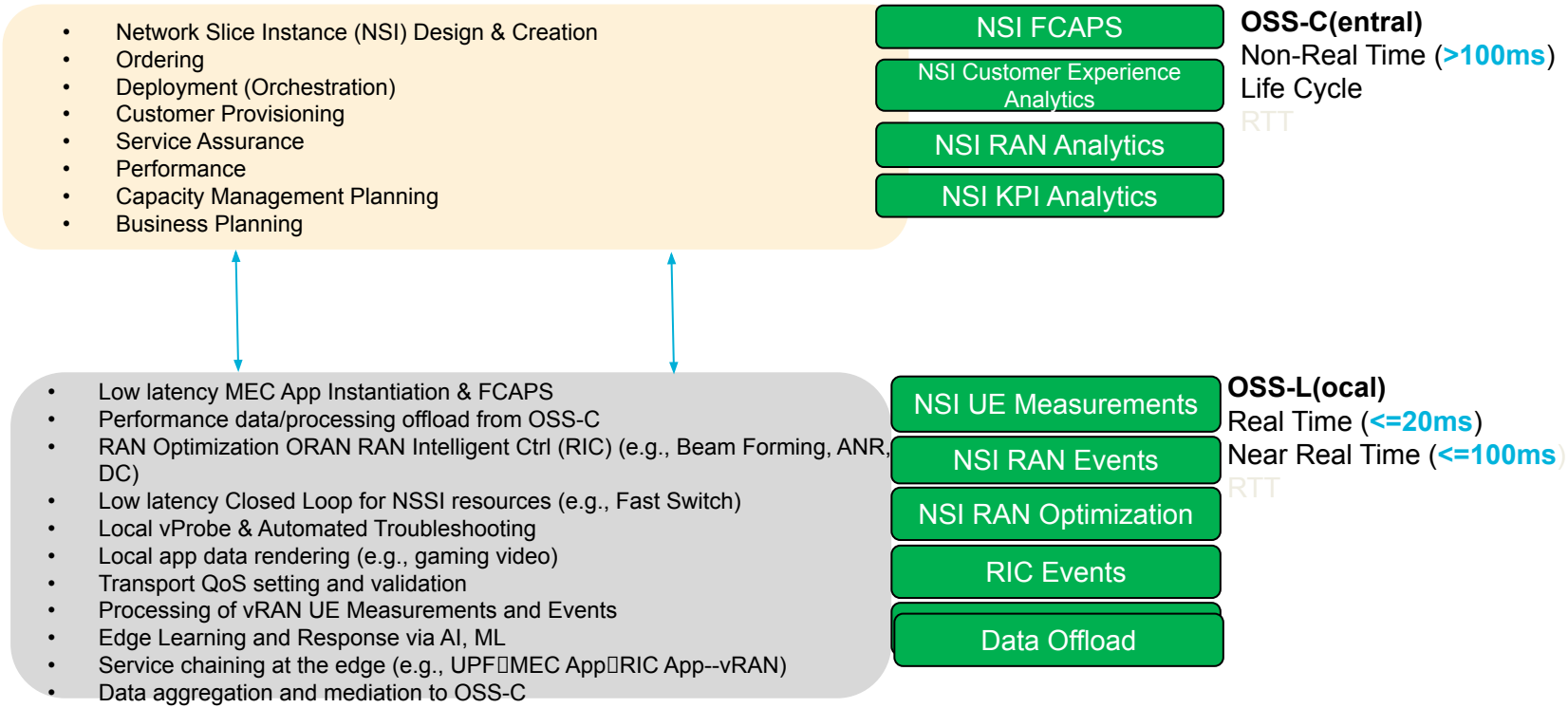
*All latency numbers are Round Trip Time (RTT) including SOL and node processing times.

OSS Future Mode of Operation (FMO) with Network Slicing

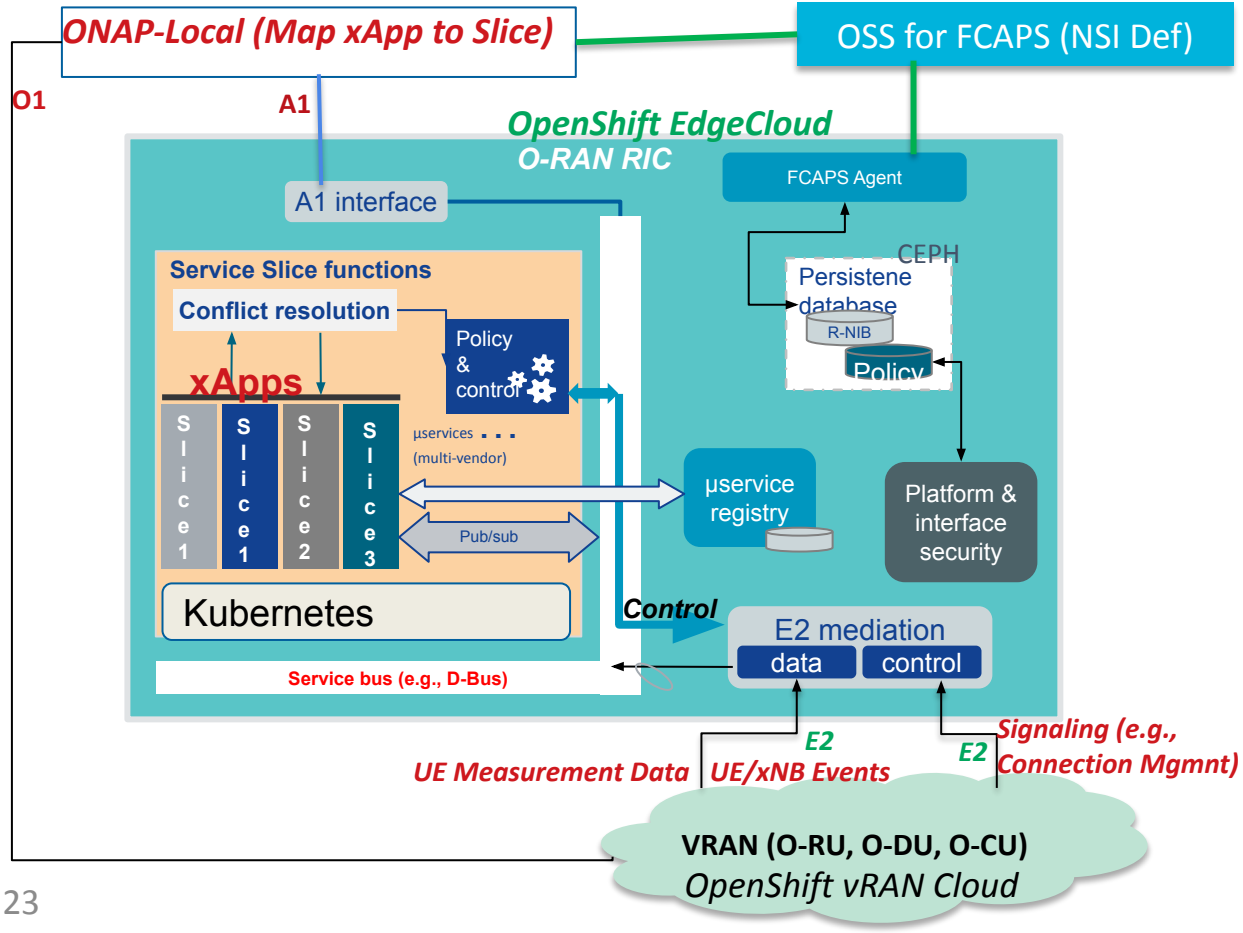
- Distributed OSS Model
  - OSS-Central, OSS-Local
  - Proposed NSI stack
- OSS-C Role
  - E2E Network Slice Instance (NSI) Design, Creation and Lifecycle
  - NSI Non-RT FCAPS, Planning
  - Network Non-RT FCAPS
- OSS–L Role
  - OSS-C data offload
  - FCAPS of low-latency NSSI components within the Edge



OSS NSI Life Cycle Model using OSS-C & OSS-L



Example OSS/BSS Architecture with O-RAN RIC NSI Integration



OSS-C/BSS-C

- Focus on infrastructure and NSI def, NSI orchestration and FCAPS
- ***RIC xApps, MEC micro-services mapped to SliceN by ONAP-L***
- Orchestration is Non-RT but services orchestrated may be RT or Near-RT in nature (e.g., AV, Robotic Surgery)
- Slice configs "Pushed" to MEC

RIC Slicing via xApps

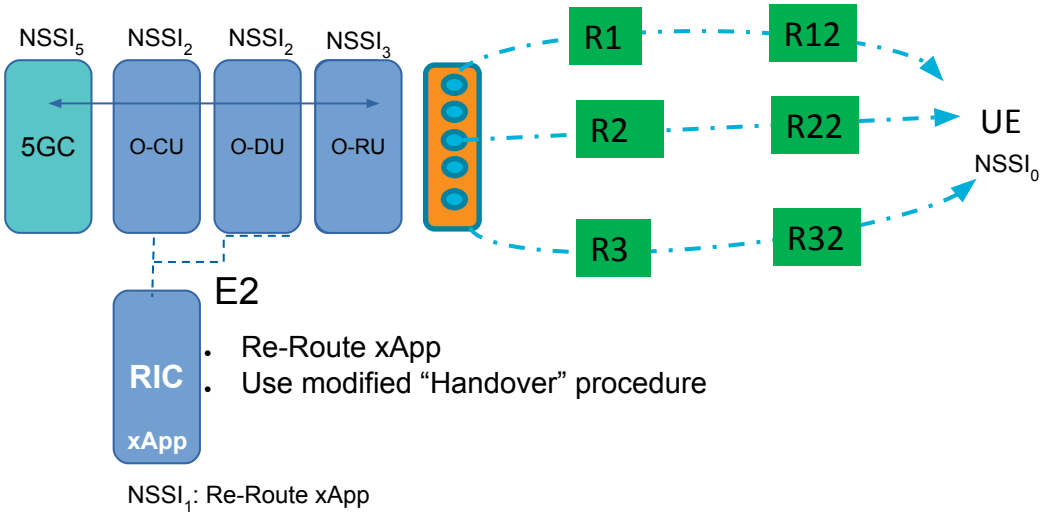
- Carrier-grade EdgeCloud (e.g., OpenShift)
- ***RIC xApps, MEC Mservices mapped to SliceN by ONAP-L (e.g., 2 xApps in 1 Slice)***
- Each "Slice" disaggregates vRAN CP/UP components to provide differentiated RAN optimization per SliceN
- Focus on RT & Near-RT Low-latency use cases
  - E.g., ANR which may require RT or NRT latency (<=10ms)
  - E.g., Dual Connectivity, Beam Forming

ONAP-Local

- Low latency Closed-Loop-Orchestration, Management
- Manage O-RAN and vRAN via standard ORAN/xRAN interfaces (A1, O1, E1, E2)
- Shares management responsibility with OSS/BSS
- Data Mediation, Insight Generation
- Policy, xApp to Slice mapping

Example NSI: Improving Performance of Network Beam Steering using mmWave and Massive MIMO

- Multiple Input Multiple Output Antenna at Macro-cell
- Use Network of Smart-repeaters and/or Small-cells to route around obstacles or “bad links”
- Beam Forming and Steering per UE
  - Network Beam Steering where obstacles, blockage, refraction, dispersion are problematic



- $NSSI_1$ = RIC Re-Route xApp
- $NSSI_2$ = O-CU and/or O-DU port bandwidth (e.g., Port 1.x, where x = logical sub-port)
- $NSSI_3$ = O-RU port bandwidth
- $NSSI_4$ = UE NSI Application
- $NSSI_5$ = Core Network Function(s) needed
- $NSSI_{6-8}$ = Front, Mid, Back Haul
- $NSSI_0$ = R1-R32 = Intelligent Repeaters/Micro-Cells/Smallcells path to UE App

Cyber Security in 5G NSI

- **Vertical Security via Slicing: Distinct Virtual Networks**
  - Physical infrastructure is multiplexed into virtual Network Slice Instances (NSI)
    - MNOs/MVNOs want to monetize the network via Virtual Network Slices
  - Network Slices minimize or eliminate common data structures between NSI
  - Hardware and Firmware commonality between NSI is easier to firewall
  - Each NSI maintains a unique set of SLAs, QoS, CoS, and FCAPS
- **Horizontal Security:**
  - **5G UP & CP Encryption**
    - Protection against eavesdropping and modification
    - Signaling traffic and bearer data is encrypted
      - Encryption based on SNOW 3G, AES-CTR, and ZUC
      - Key generation based on HMAC-SHA-2569
  - **New Integrity Protection**
    - Based on SNOW 3G, AES-CMAC, and ZUC
    - Applies to small, bursty data as would be expected from IoT devices

Cyber Security in 5G (cont'd)

- **Horizontal Security (cont'd)**
  - **Identity Management**
    - ✔ Secure methods for authenticating subscribers (apply to each NSI)
    - ✔ 5G Authentication & Key Agreement (5G AKA) and Extensible Authentication Protocol (EAP)
    - ✔ MNO/MVNO determines authentication credentials, methods, and ID formats for subscribers (incl devices)
    - ✔ Previous releases required SIM cards
    - ✔ 5G accepts certificates, pre-shared keys token cards, and other objects
    - ✔ EAP allows for different authentication protocols and credential types without affecting intermediate nodes
  - **5G inherits Equipment Identity Register (EIR)**
    - ✔ **Prevents stolen devices from using network services**
  - **Subscriber Presence Validation**
    - ✔ MNO/MVNO validates subscriber presence during authentication (including Roaming)
    - ✔ Identifies and mitigates fraud for the Carrier/Operator and the subscriber

Backup

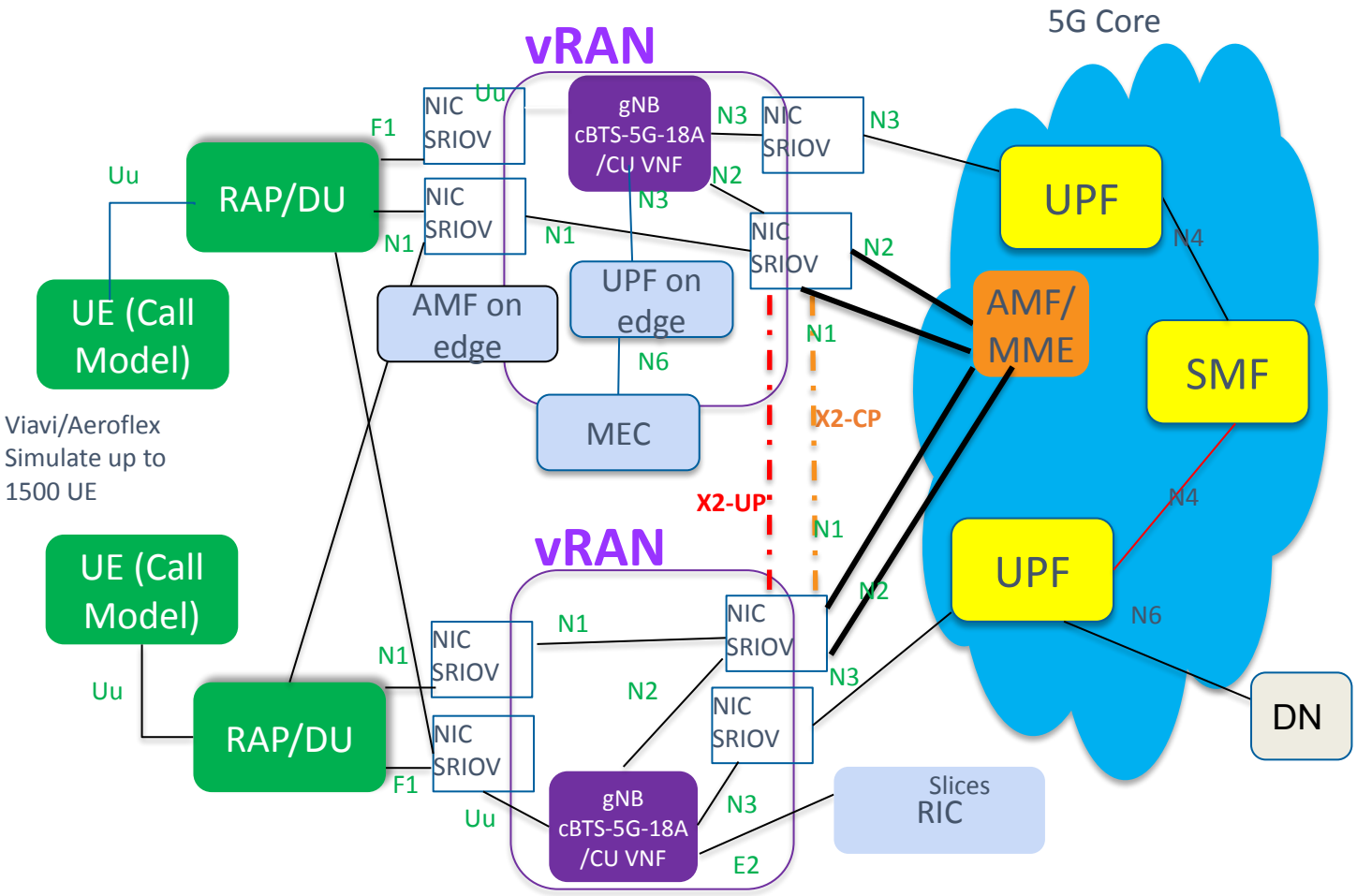
5G Service Slicing - Definitions

- ***NSI*** **(Network Slice Instance): Virtual service overlay on a common physical network.**
  - Each NSI provides a specific service capability that is isolated as a logical entity from other Slices. For example, VoLTE can be considered a service slice over a physical LTE network.
  - Physical and logical resources can be dedicated to particular slices.
  - Network Functions (NFS) from the 5G 3GPP reference architecture are arranged E2E in a slice.
- ***NSSI*** **(Network Slice Subnet Instance): A subnet, such as RAN, and associated configurations as part of the E2E NSI definition.**
- ***Micro-Services*****: A software architecture technique to instantiate service slicing.**
- ***MEC*****: Mobile Edge Cloud or Multi-Access Edge Cloud.**
- ***REC*****: Radio Edge Cloud**
- ***ORAN*****: Open-RAN Alliance**
- ***RIC*****: RAN Intelligent Controller, part of the ORAN specification**
- ***5Gc*****: The 5G Packet Core**

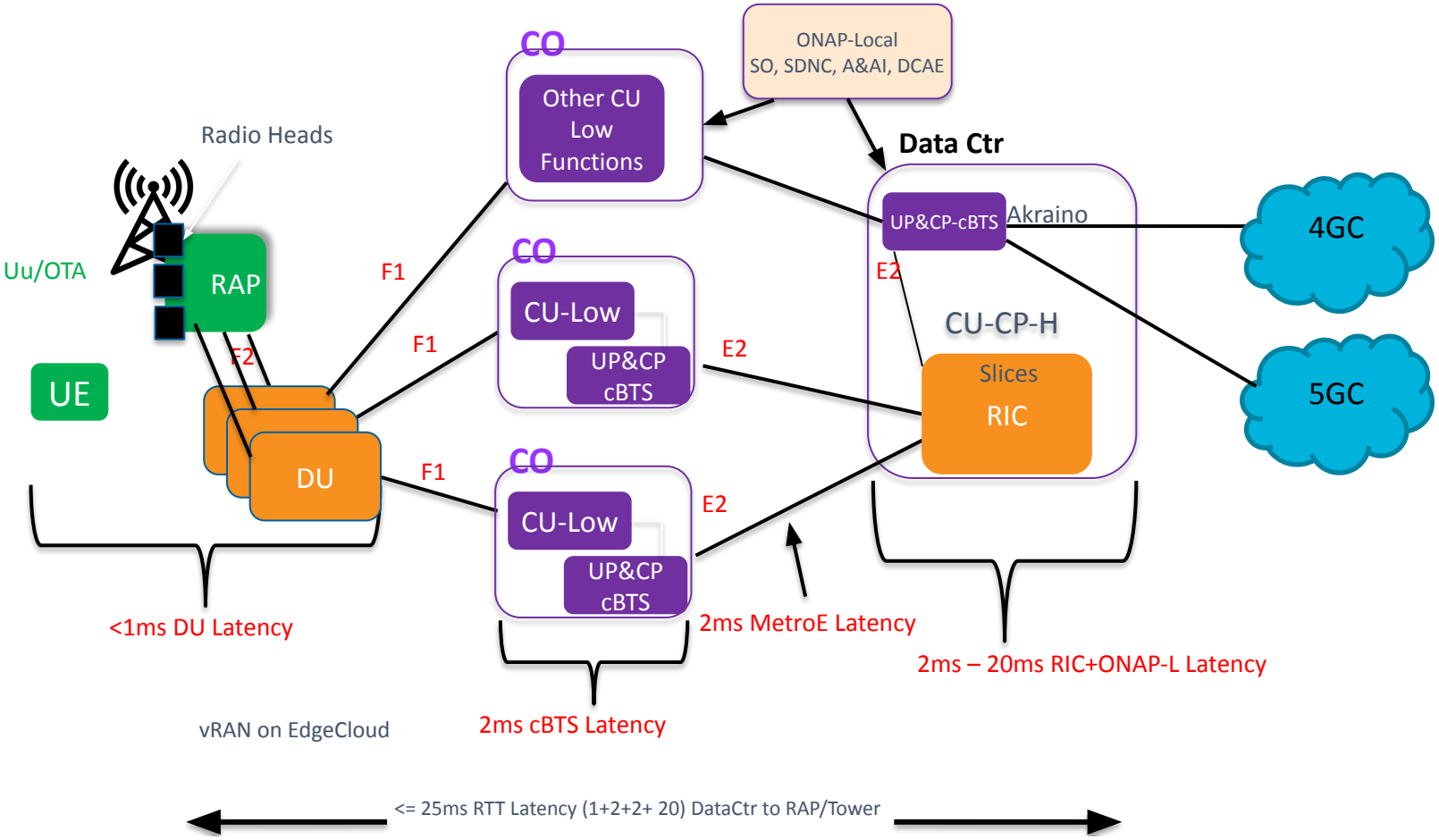
CUPS

- **Control and User Plane Separation (CUPS) architecture and spec completed in TR 23.714 and TS 23.214/23.244.**
- **CUPS enables scaling of UPF by architectural separation of control and user plane functions using Sx.**
  - UPF can be distributed and deployed independently from the centralized control plane.
  - This includes on the MEC/REC and the Far Edge (Cloud).

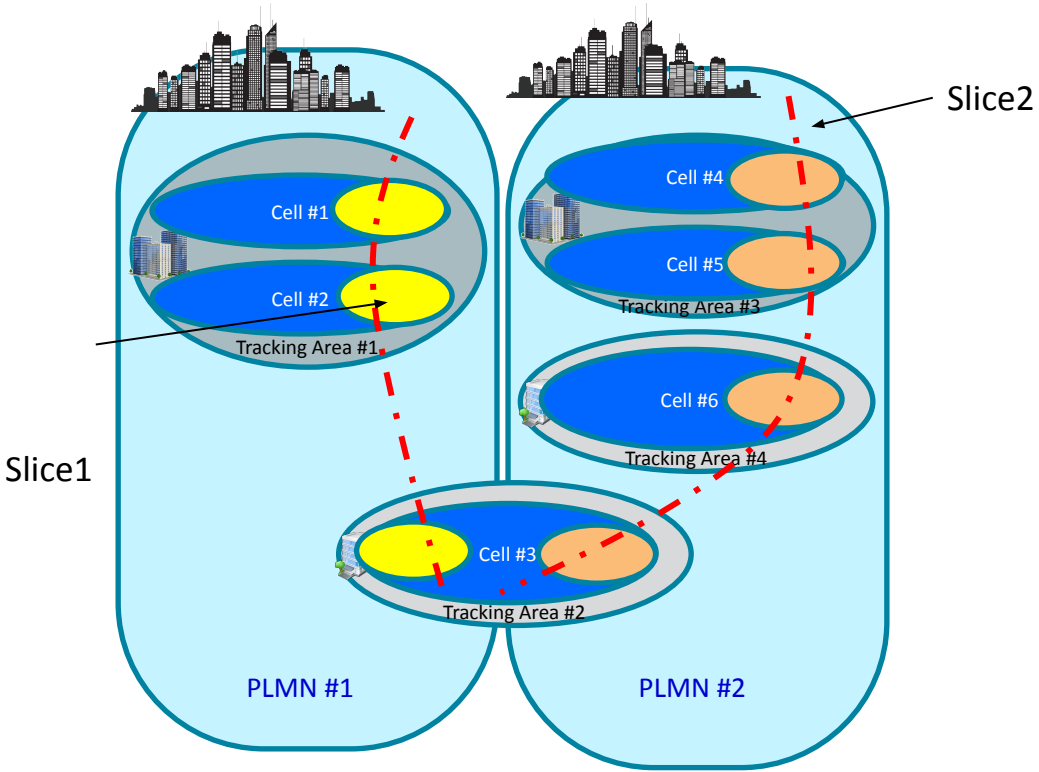
Edge Distribution of NFs Based on Service Slices



e/gNb Dis-aggregation with Latency Optimization



From AT&T RAN-Slicing POC using ONAP



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