5G Network Architecture II

COS 597S: *Recent Advances in Wireless Networks*

Fall 2024

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Outline

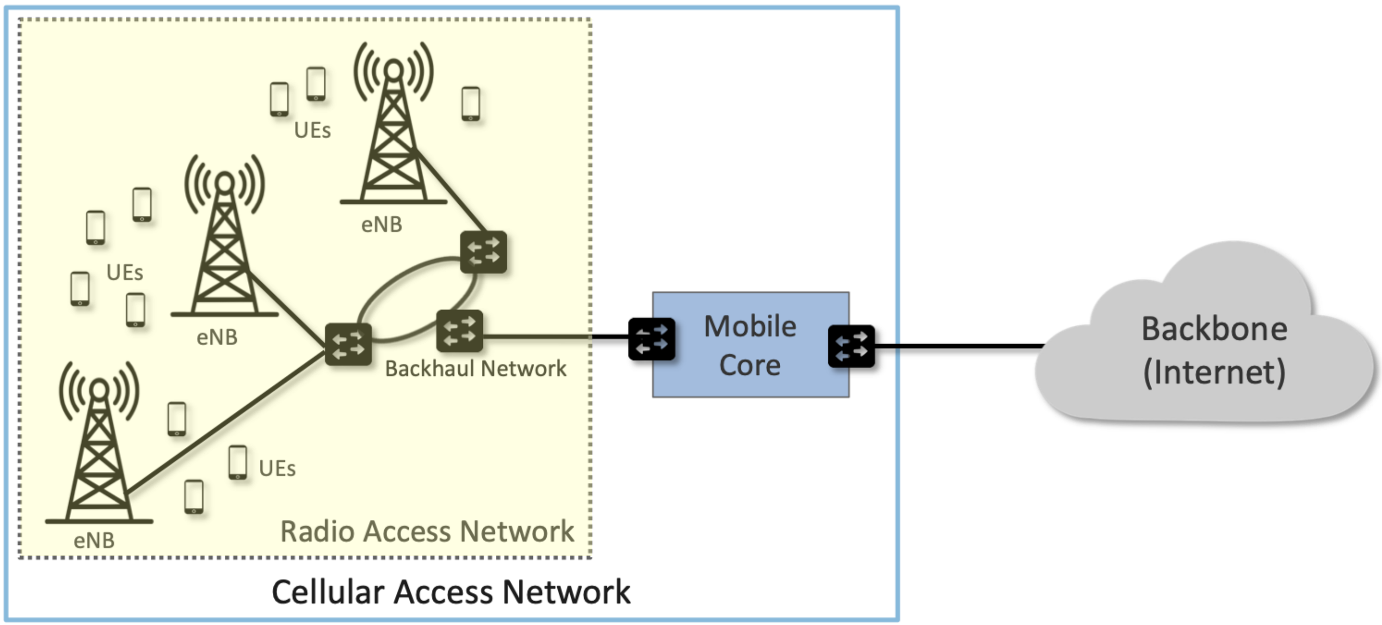
Peterson, Sunay, Davie (PSD). *Private 5G: A Systems Approach*

- **Chapter 4: Radio Access Network**
  - **Packet Processing**
  - Split RAN, Software-Defined RAN
  - Near Realtime Control

- Chapter 5: Mobile Core

Radio Access Network: Context

- Radio Access Network's high-level goal: **transfer packets** between mobile core and UEs



- **Disaggregation and distribution** of RAN: **O-RAN Alliance**

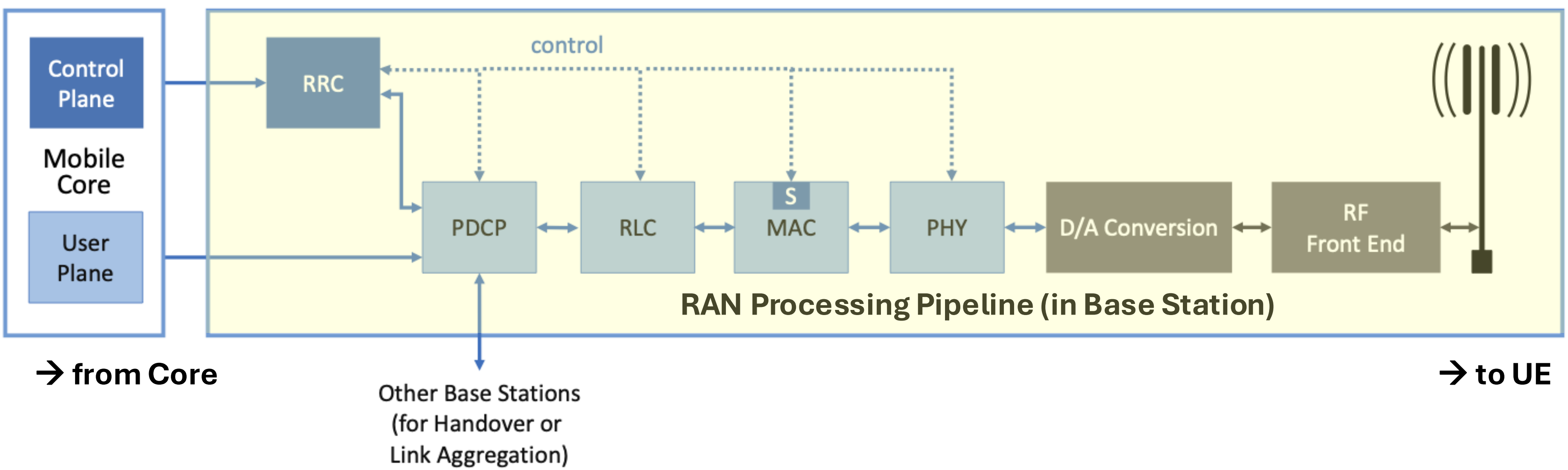
Radio Access Network: Overview

User Plane

- **PDCP** (Packet Data Convergence Protocol)
- **RLC** (Radio Link Control)
- **MAC** (Medium Access Control)
- **PHY** (Physical Layer)

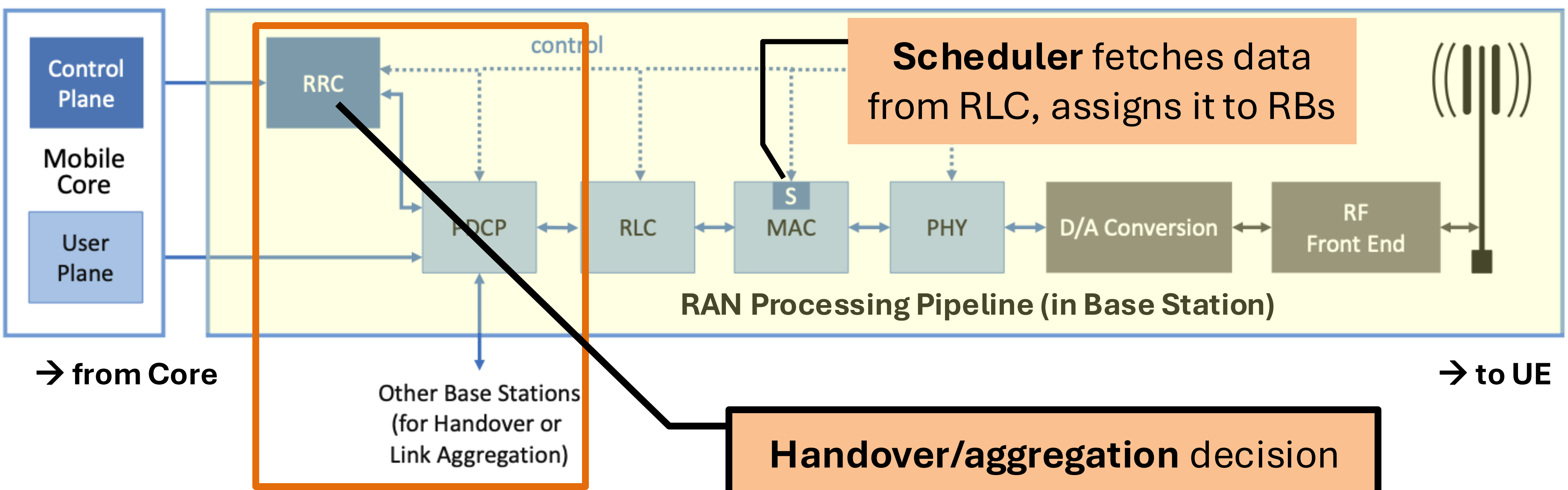
Control Plane

- **RRC** (Radio Resource Control)



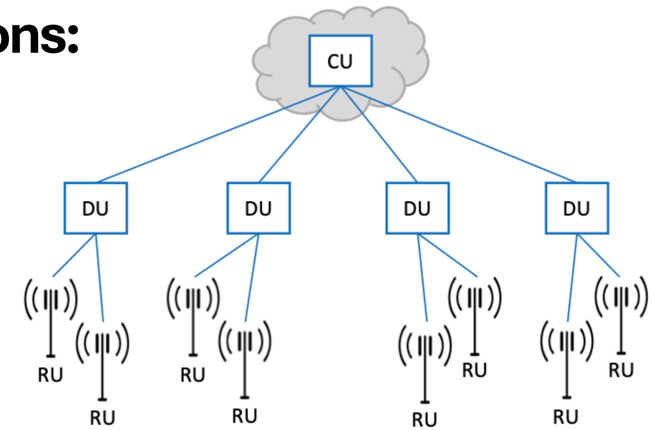
Two key RAN components: Scheduler, RRC

- **Scheduler** resides in the MAC, controls flow from RLC to PHY
- **RRC** makes handover/aggregation decisions
  - **PDCP** then "makes it so"

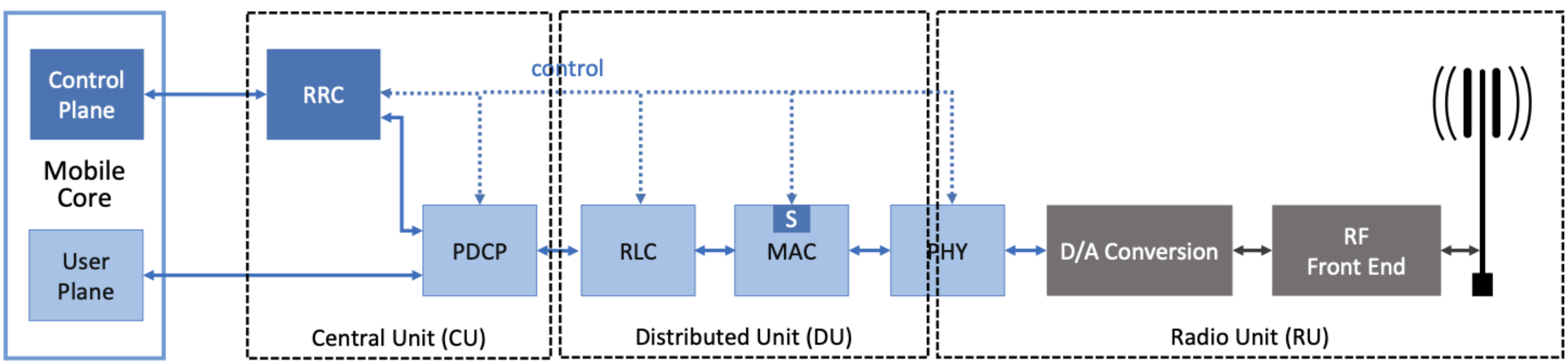


Split RAN

- **Partition** base station functionality **across locations:**



- **Central Unit (CU)** runs in **cloud**
- Serves multiple **Distributed Units (DUs)** in **field**
- Serves multiple **Radio Units (RUs)** on **towers**



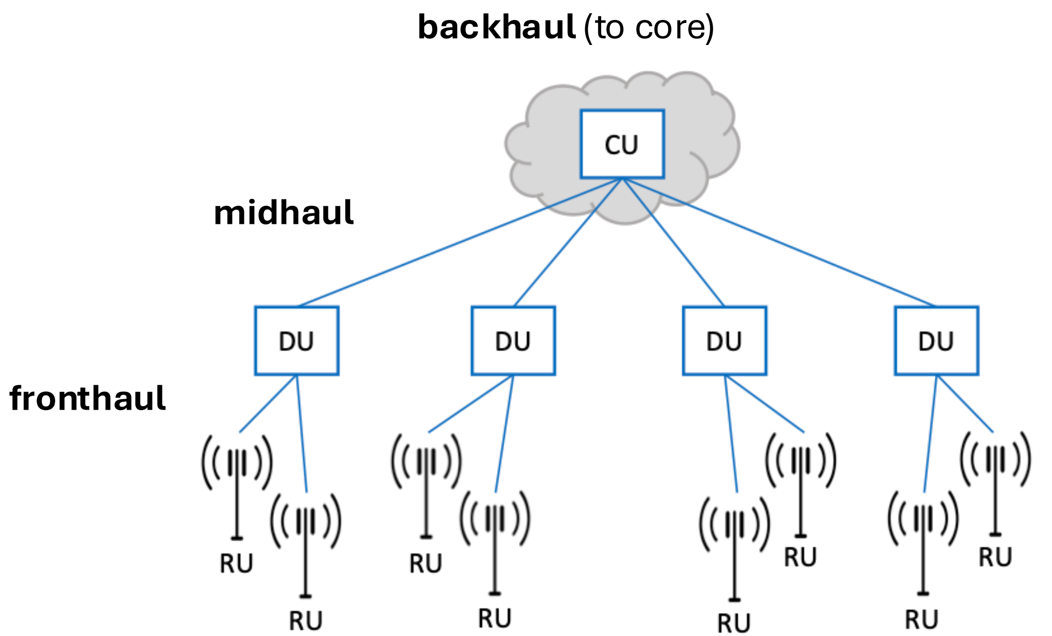
<u>Real-Time (~1 ms) v. Near-Real Time (10s of ms):</u>

- **Near-real-time** configuration and control: RRC (CU)
- **Real-time** scheduling: MAC scheduler (DU)

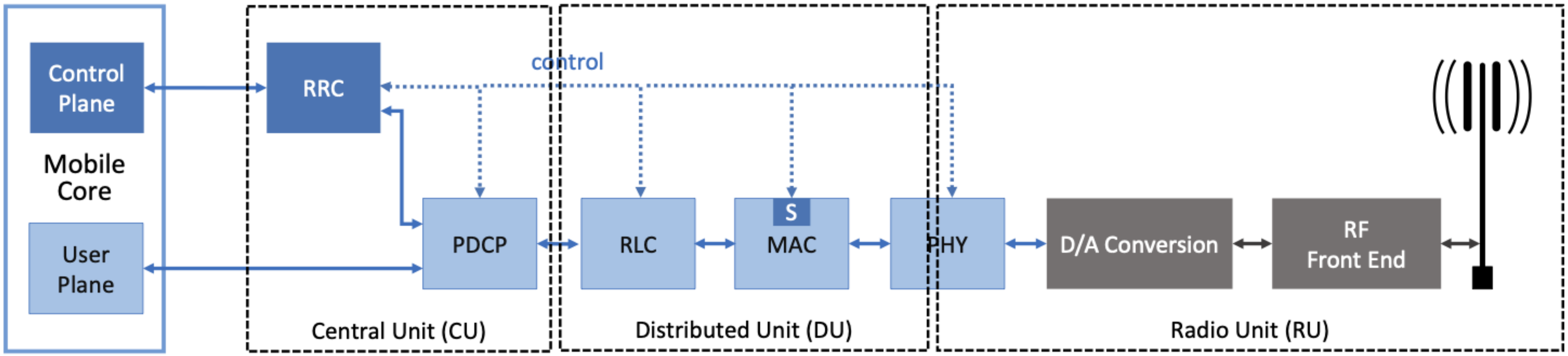
Split RAN: Co-location decisions

✓ **Co-locate** RU and DU, <u>or</u> **fronthaul** DU to many RUs

- **Maybe, co-locate** CU & Core (backhaul is data center network)
  - Then, midhaul goes to the field



Split RAN: Where is the complexity?

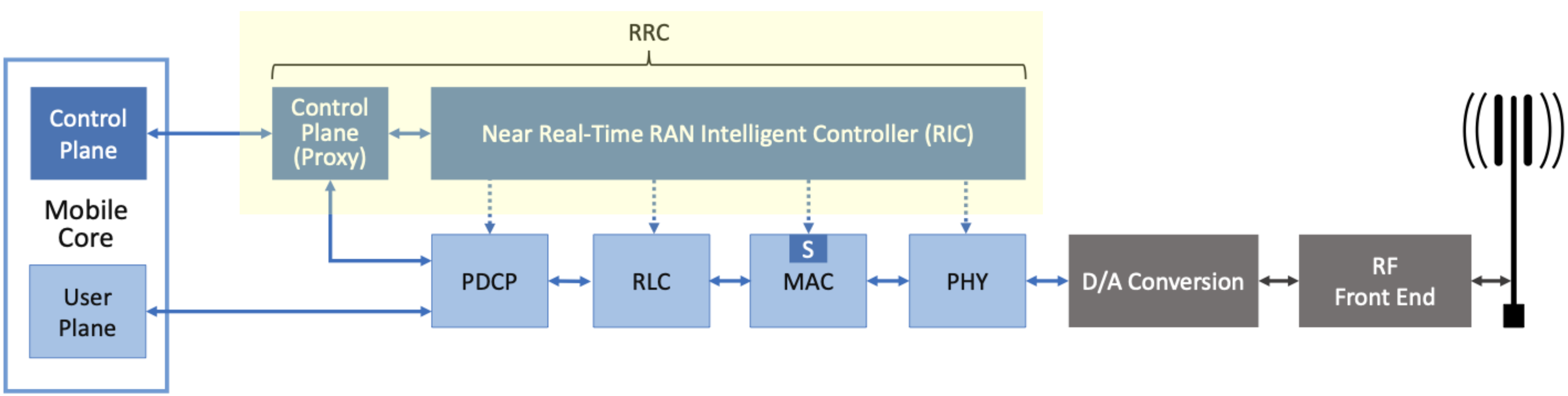


- CU contains RRC (control plane) and PDCP (user plane)
  - Most complexity in control plane (**open source available)**
- **DU High PHY** is most complex (**FlexRAN open source available)**
- **DU MAC** is also complex (**Open Air Initiative (OAI) available)**

Software-Defined RAN

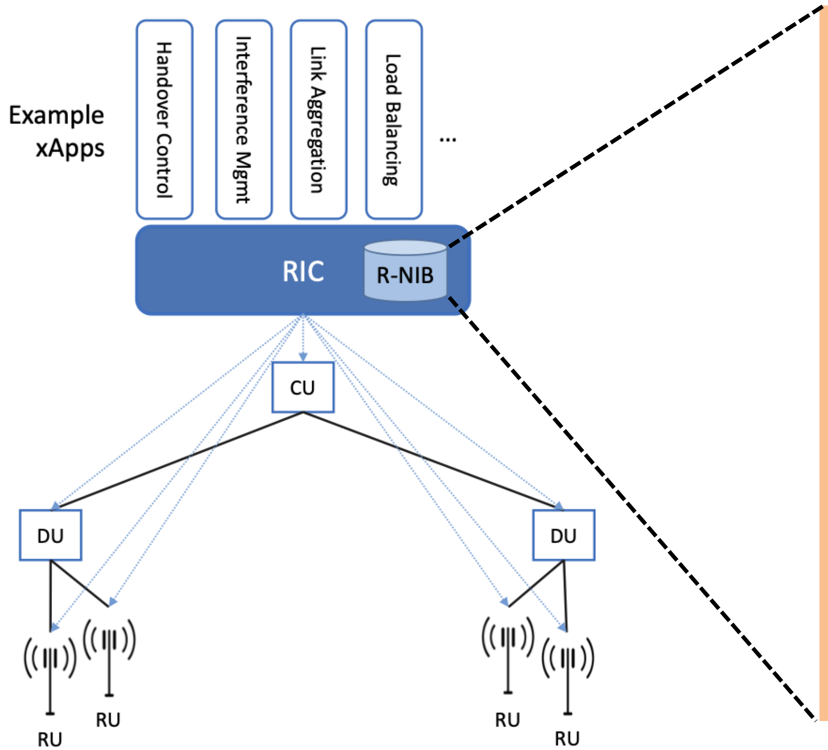
- Partition the **RRC** into ***Control Plane*** and ***Near-RT RIC***

- **Near Real-Time RAN Intelligent Controller (Near-RT RIC)**
  - Enables **software-based control** of RAN stages (at 10-100 ms timescales)



Inside the Near-RT RIC

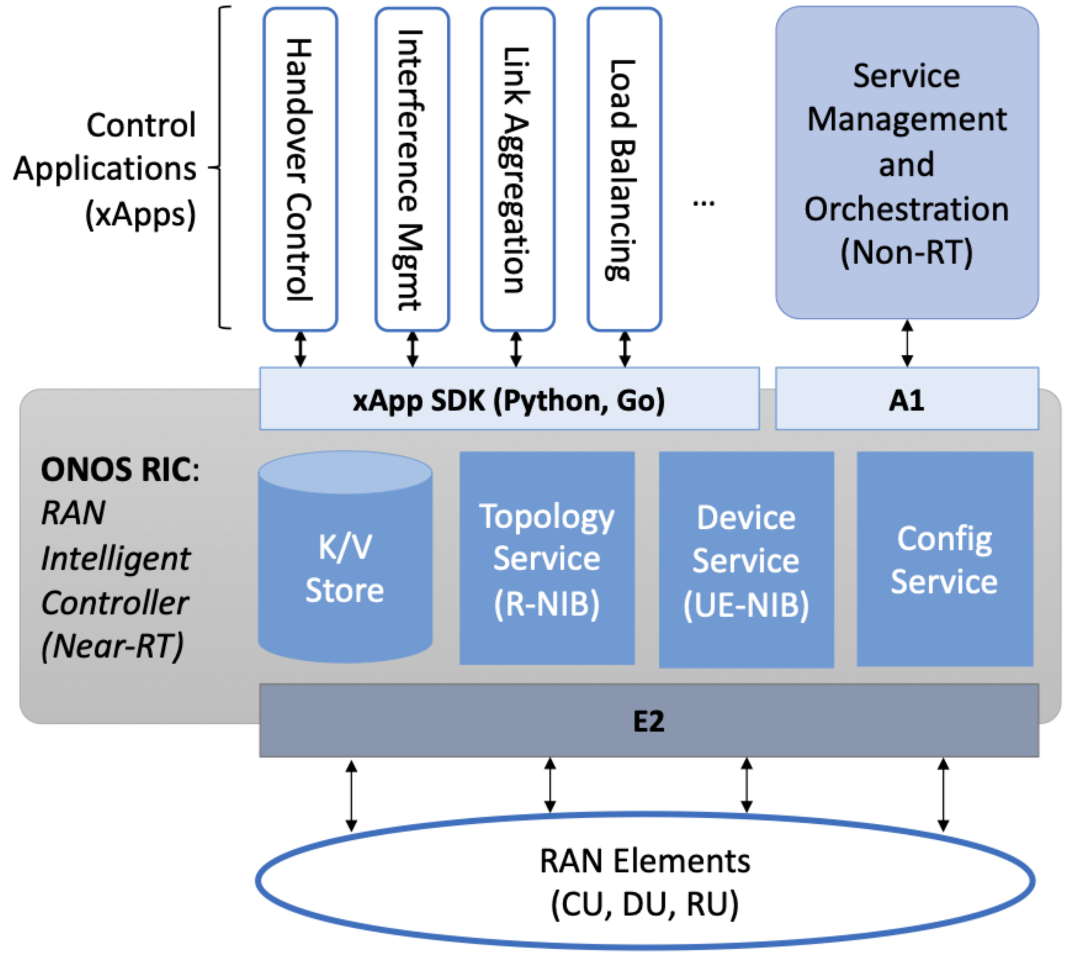
- Maintains RAN Network Information Base (**R-NIB**)
- Near-RT RIC hosts SDN control "apps" (**xApps**)



- Fixed Nodes (RU/DU/CU Attributes)
  - Identifiers
- Mobile Nodes (UE Attributes)
  - Devices
    - Identifiers
    - Capability
    - Measurement Config
    - State (Active/Idle)
  - Links (*Actual* and *Potential*)
    - Identifiers
    - Link Type
    - Config/Bearer Parameters
    - 5QI Value
- Virtual Constructs (Slice Attributes)
  - Links
  - Bearers/Flows
  - MAC RRM Configuration
  - RRM Control Configuration

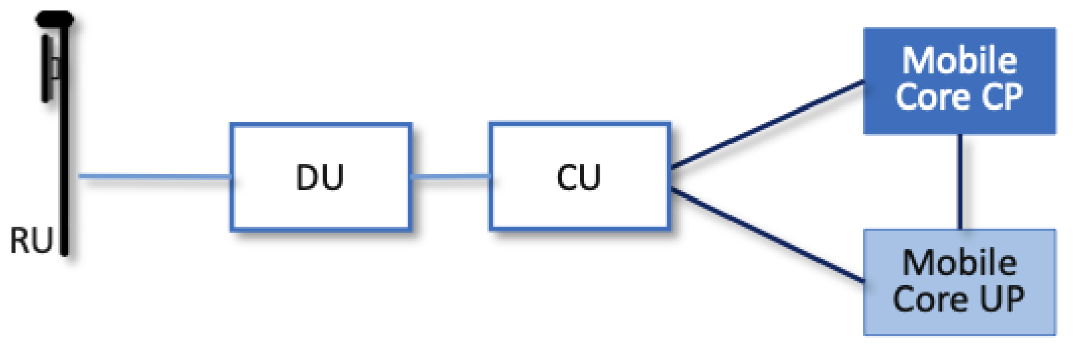
ONOS RIC: An example open source Near RT-RIC implementation

- **Open Network OS (ONOS)**
- Operator's **business logic** (SMO) configures RAN via **A1**
- ONOS RIC controls RAN via **E2**



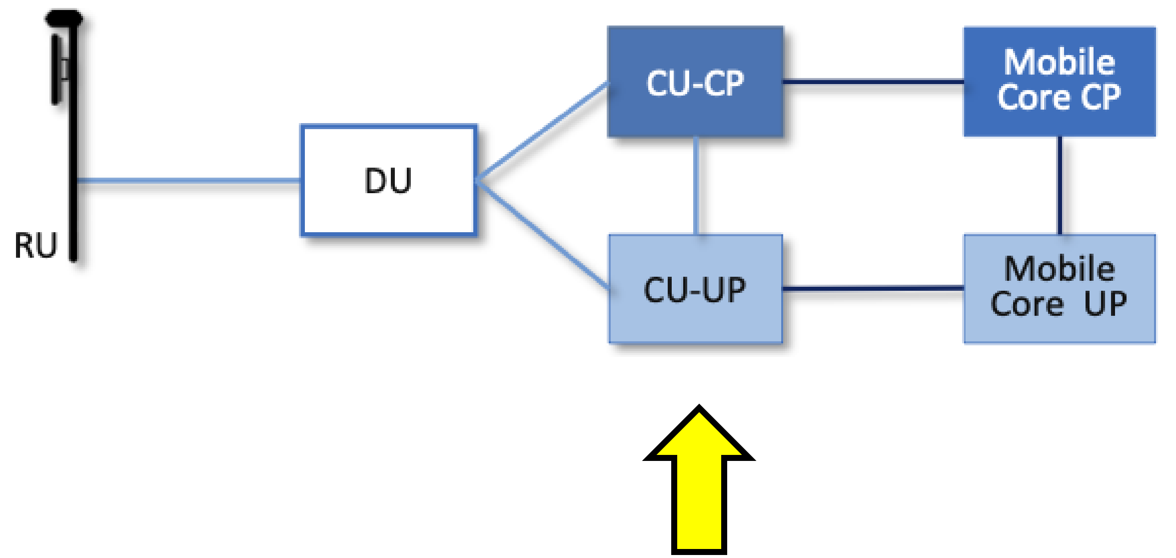
Sunmary: Steps in Disaggregation

- **Step 1- Split RAN**: defining the CU, DU, and the RU



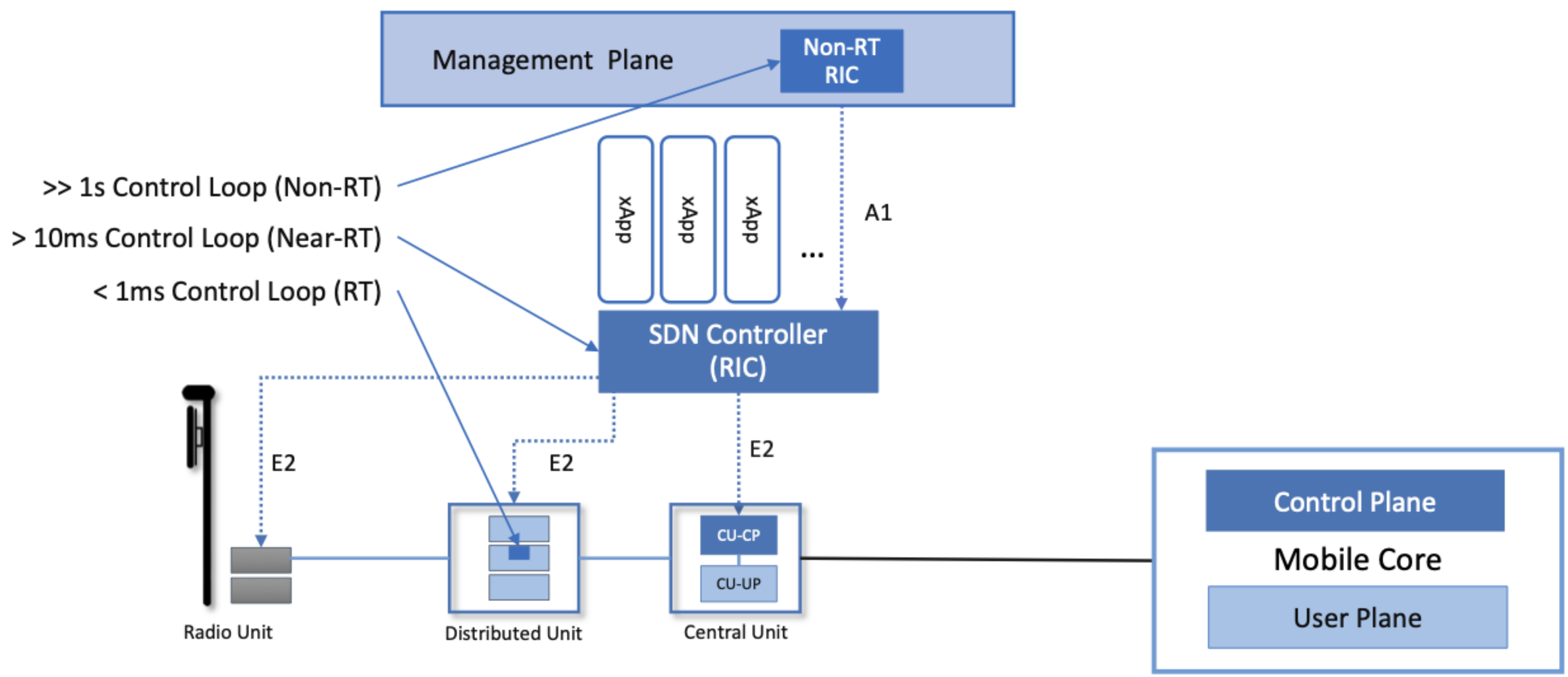
Sunmary: Steps in Disaggregation

- **Step 2- Control/User Plane Separation** (CUPS) of CU



Summary: Steps in Disaggregation

- Step 3- A Software-Defined RAN Controller



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- Chapter 4: Radio Access Network
- **Chapter 5: Mobile Core**
  - Control Plane
  - User Plane

Two perspectives

- **"Internet-centric"** view
  - Each core instance is a **router** that connects a RAN to the **global Internet**
  - Unique global identifier: **IP address**

- **"3GPP-centric"** view
  - Distributed set of cores cooperate to synthesize many RANs into a **global RAN**
  - Unique global identifier: **IMSI**

Globally routable mobile network

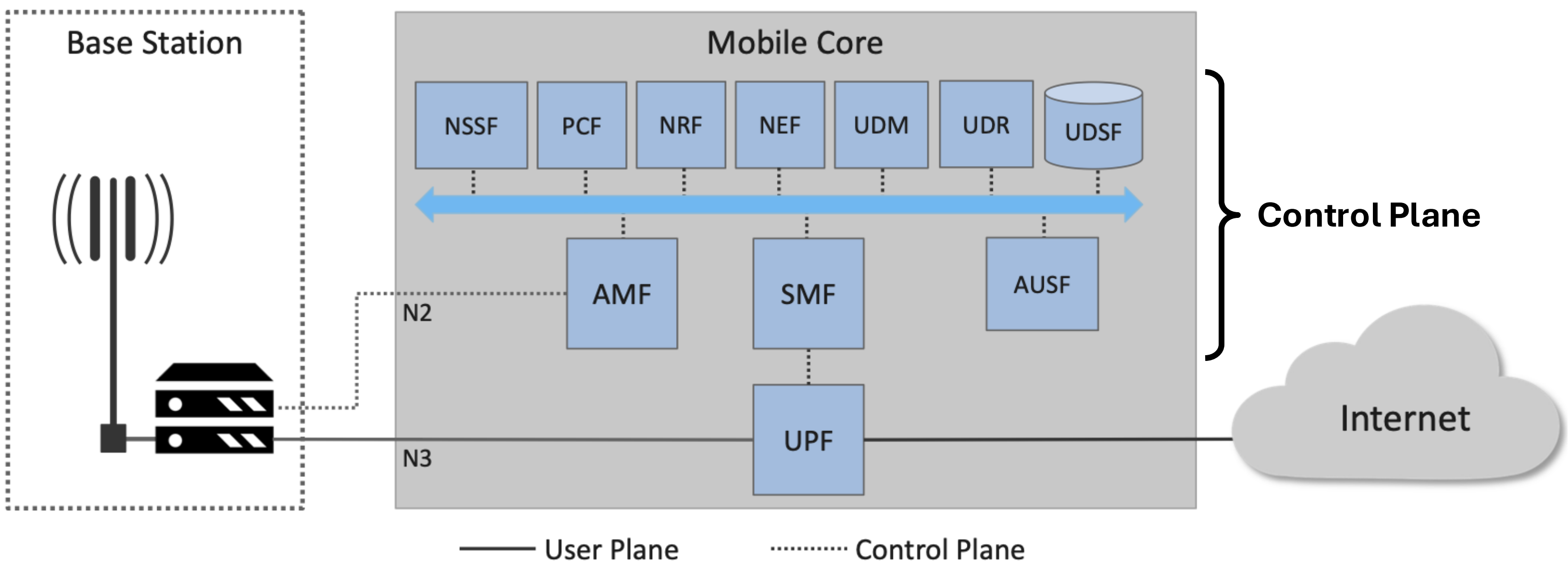
- ***Identity*** of a principal user *v.* ***identifier*** of a device

- International Mobile Subscriber Identity (IMSI) is a UE identifier 🤔 (like an Ethernet MAC address)
  - IMSI assignment is similar to MAC assignment

- IMSI **supports global routing** in the mobile network
  - Distributed database **maps** **IMSI** to current **mobile core** id
    - 4G: Home Subscriber Server (HSS); 5G: Unified Data Management (UDM)
  - Mobile core tracks device as it moves base stations

Core Functional Components

- **User Plane Function** (UPF) forwards between RAN, Internet
- **Control Plane:**
  - Access and Mobility Management Function (**AMF**)
  - Session Management Function (**SMF**)



Implementing the Control Plane

- SD-Core (Software-Defined Core)
  - Elements run in **Kubernetes-hosted containers**
  - Supports both 4G and 5G cores

- Magma
  - Designed for **remote/rural** with poor backhaul connectivity
  - Places mobile core functionality next to radio
    - Backhaul = Internet connectivity

User Plane Function

- Forwards packets to UEs, with buffering
- Uses **Packet Detection Rules** (PDRs) to action packets
  - **Forwarding Action Rules** (FARs) choose up- *v.* down-link
  - **Buffering Action Rules** (BARs) initiate buffering
  - **Usage Reporting Rules** (URRs) report per-UE usage to CP
  - **Quality Enforcement Rules** (QERs): reserve or cap capacity on a per-UE basis
    - **UPF traffic policing** enforces QERs

Up next:

Paper Discussion: EdgeRIC (XC)

Ko et al., "EdgeRIC: Empowering Realtime Intelligent Optimization and Control in NextG Cellular Networks"