5G Work

CEWiT

(Centre of Excellence in Wireless Technology, IIT Madras)

Radio Access Network

- Physical Layer L1
- Higher Layer/ L2/L3
- Control & Monitoring
- Interface to Algorithms

Physical Layer
Sub Components Developed by CEWiT in Collaboration With IITM

L1 – Sub Components and Band Width Supported

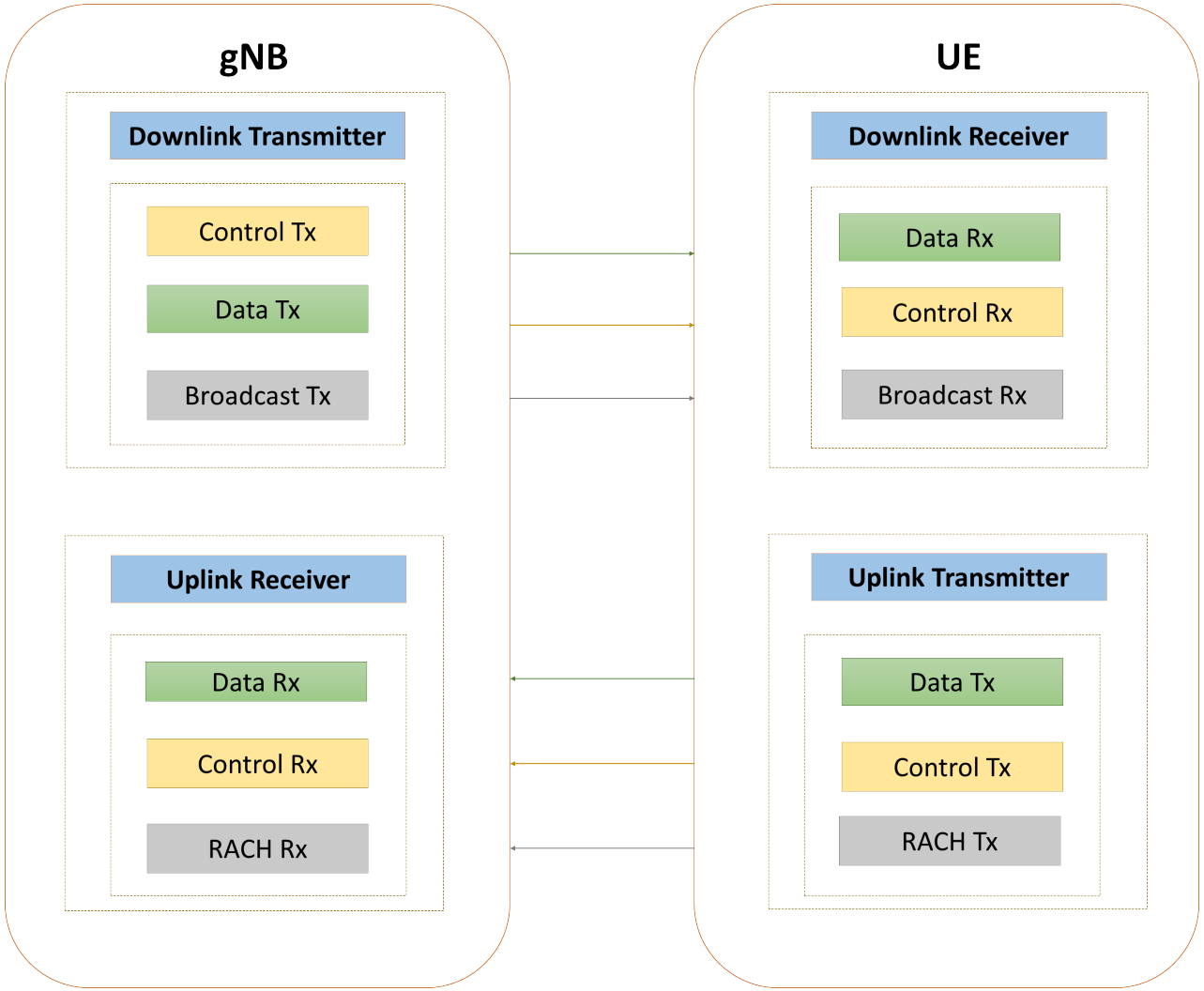
Sub 6 GHz and mm Wave

- gNB
  - Transmit Chain and Receive Chain
- UE
  - Transmit Chain and Receive Chain

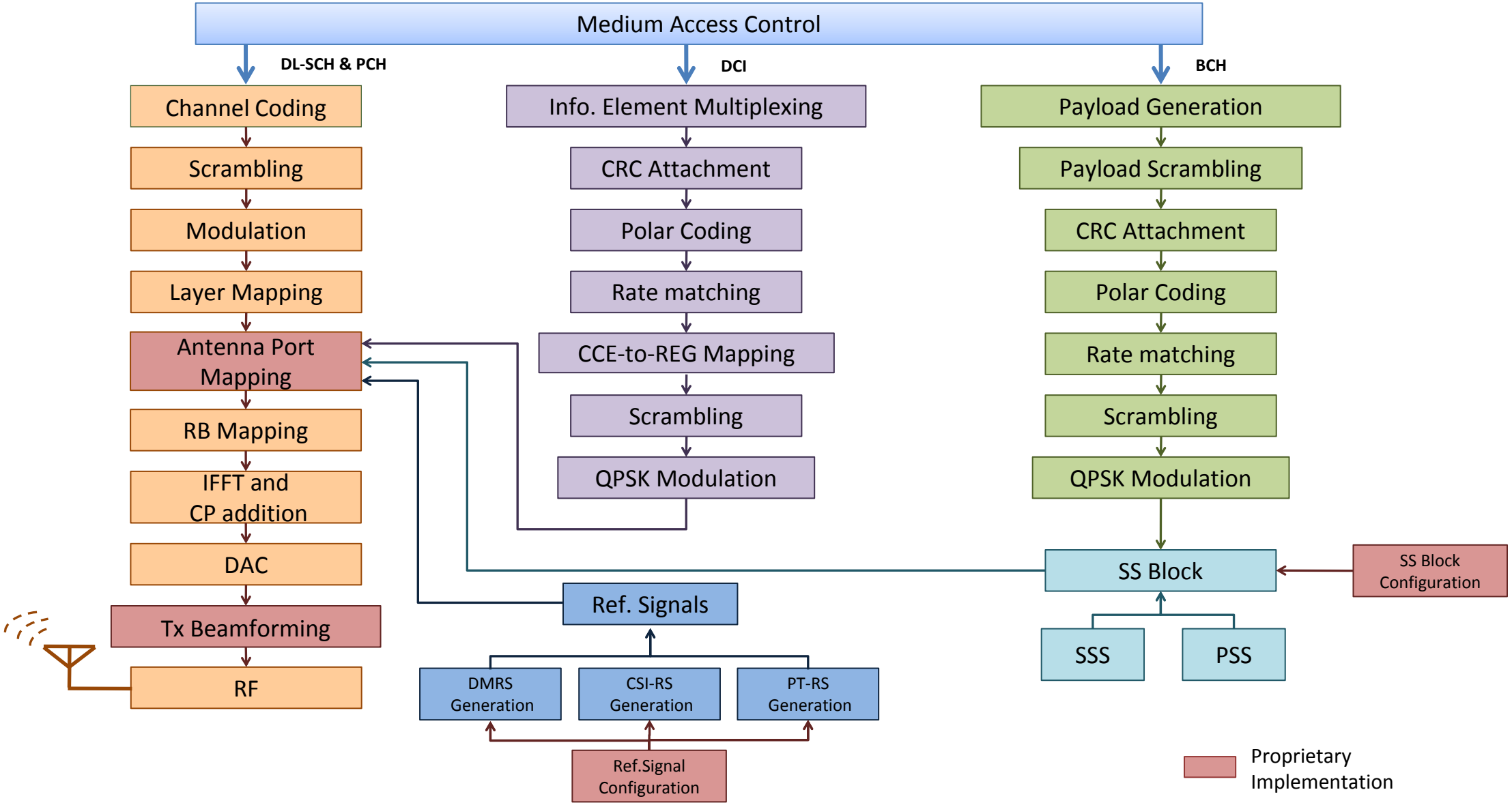
Bandwidth Supported

- gNB
  - 100 MHz for Sub 6 GHz
  - 400 MHz for mm Wave
- UE
  - 100 MHz for Sub 6 GHz
  - 400 MHz for mm Wave

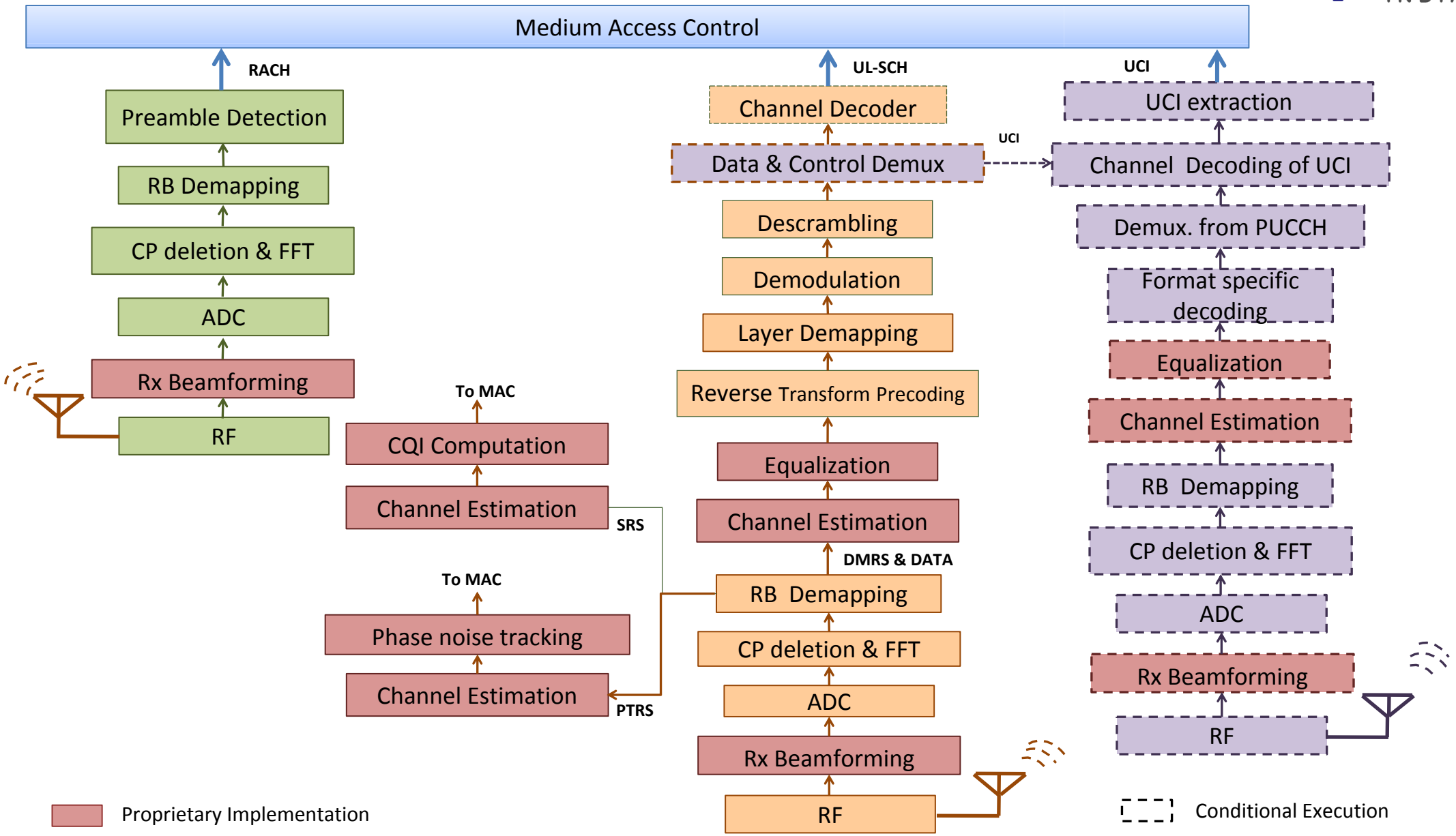
5G NR – gNB and UE



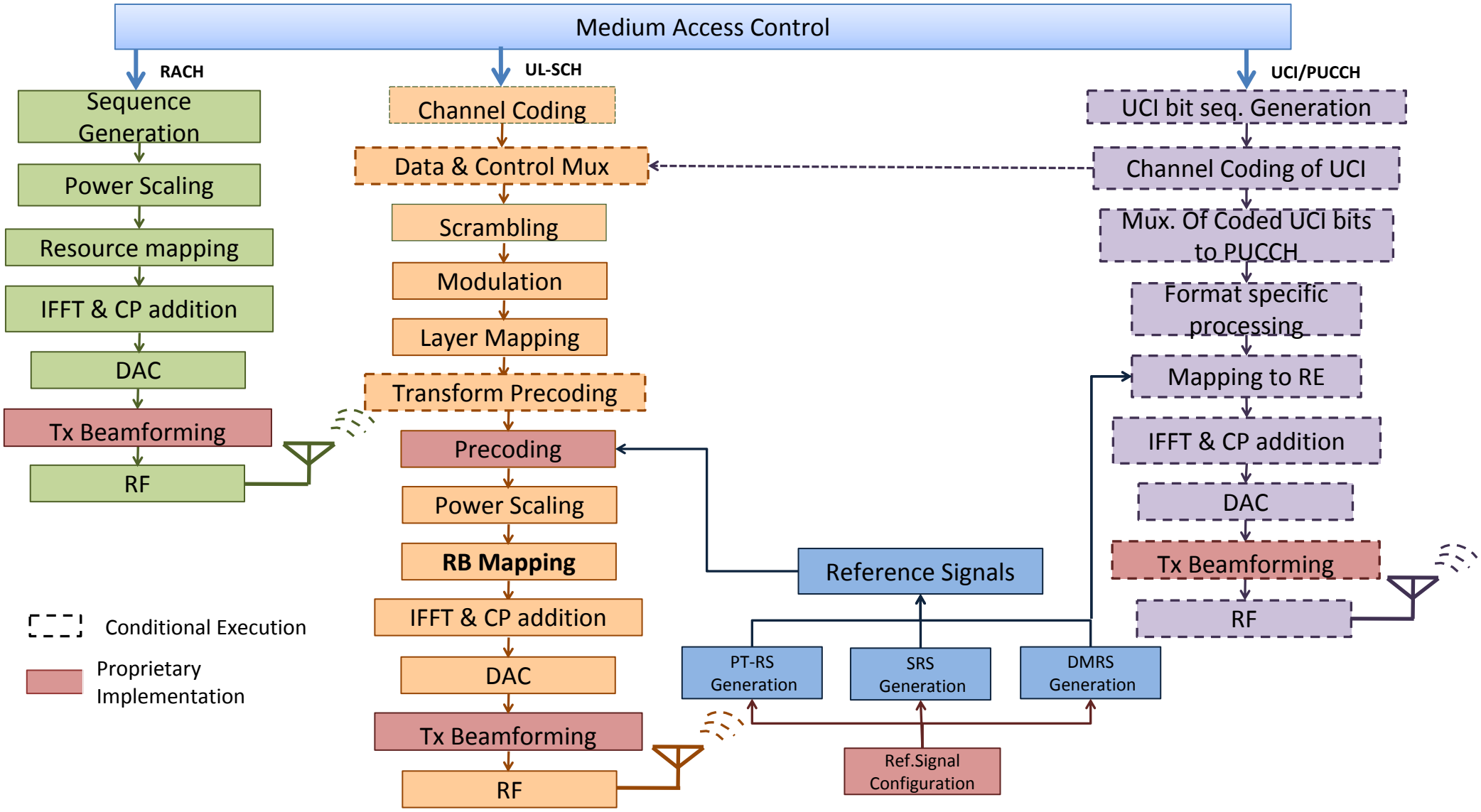
Transmit Chain at gNB



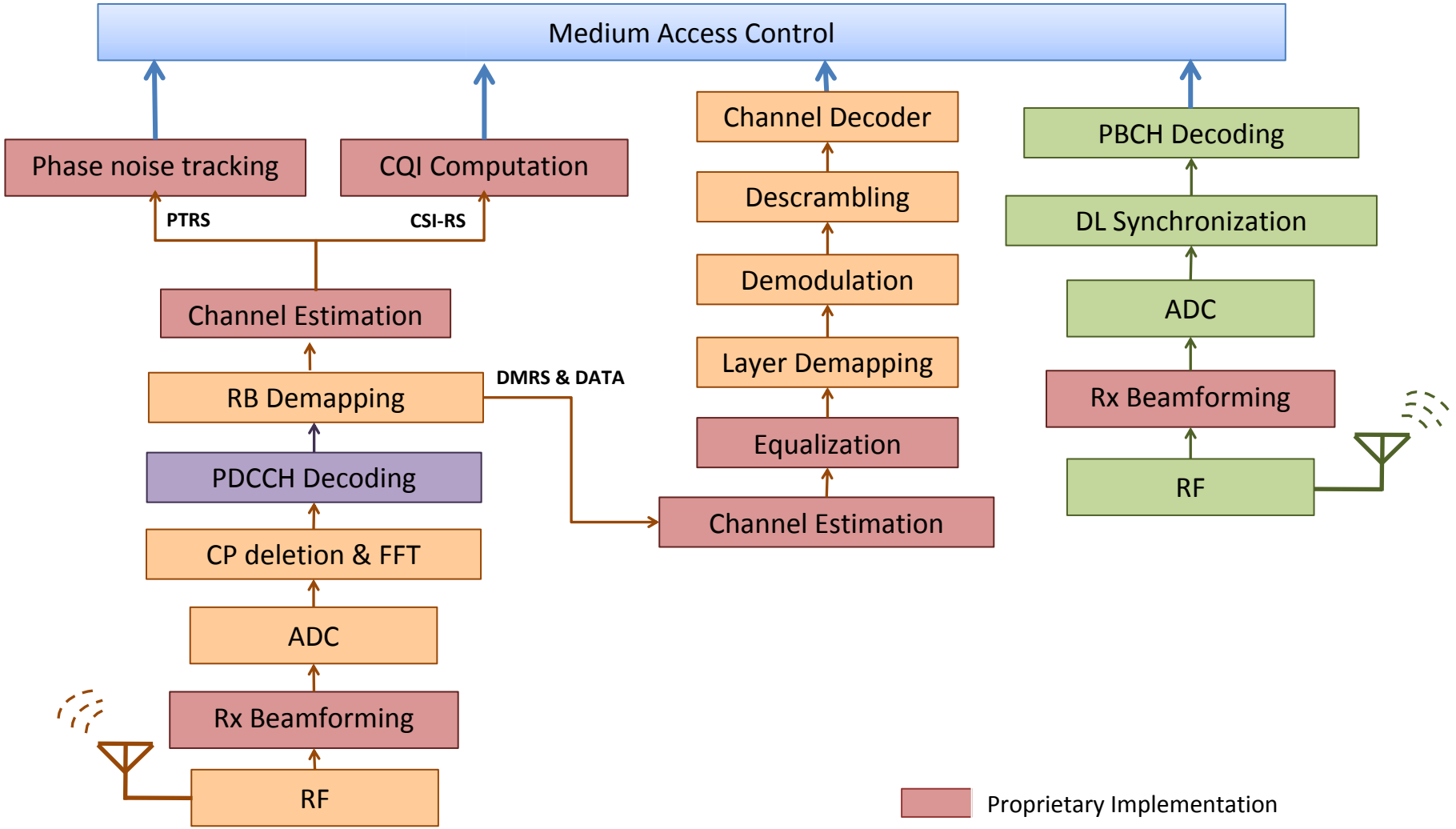
Receive Chain at gNB



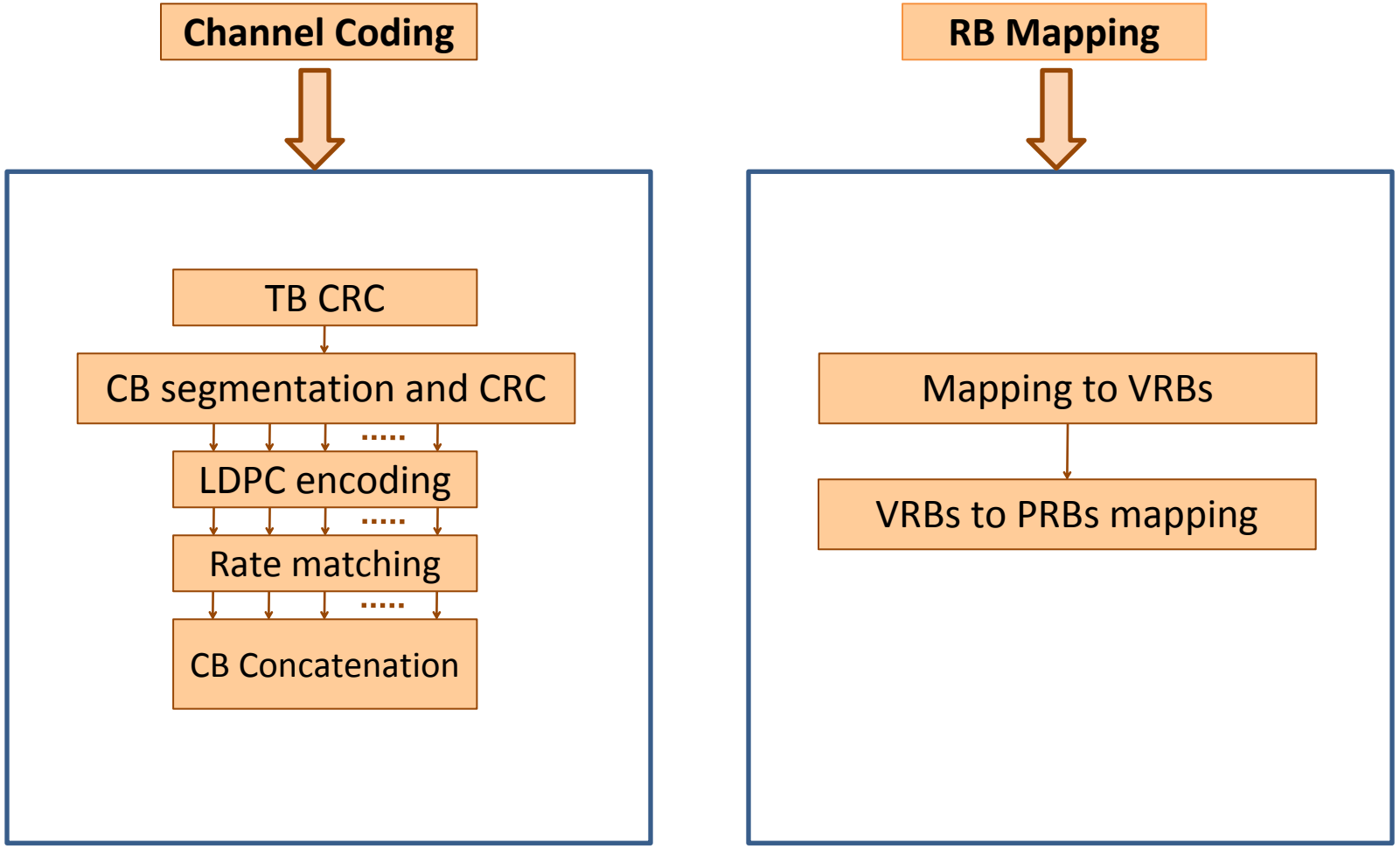
Transmit Chain at UE



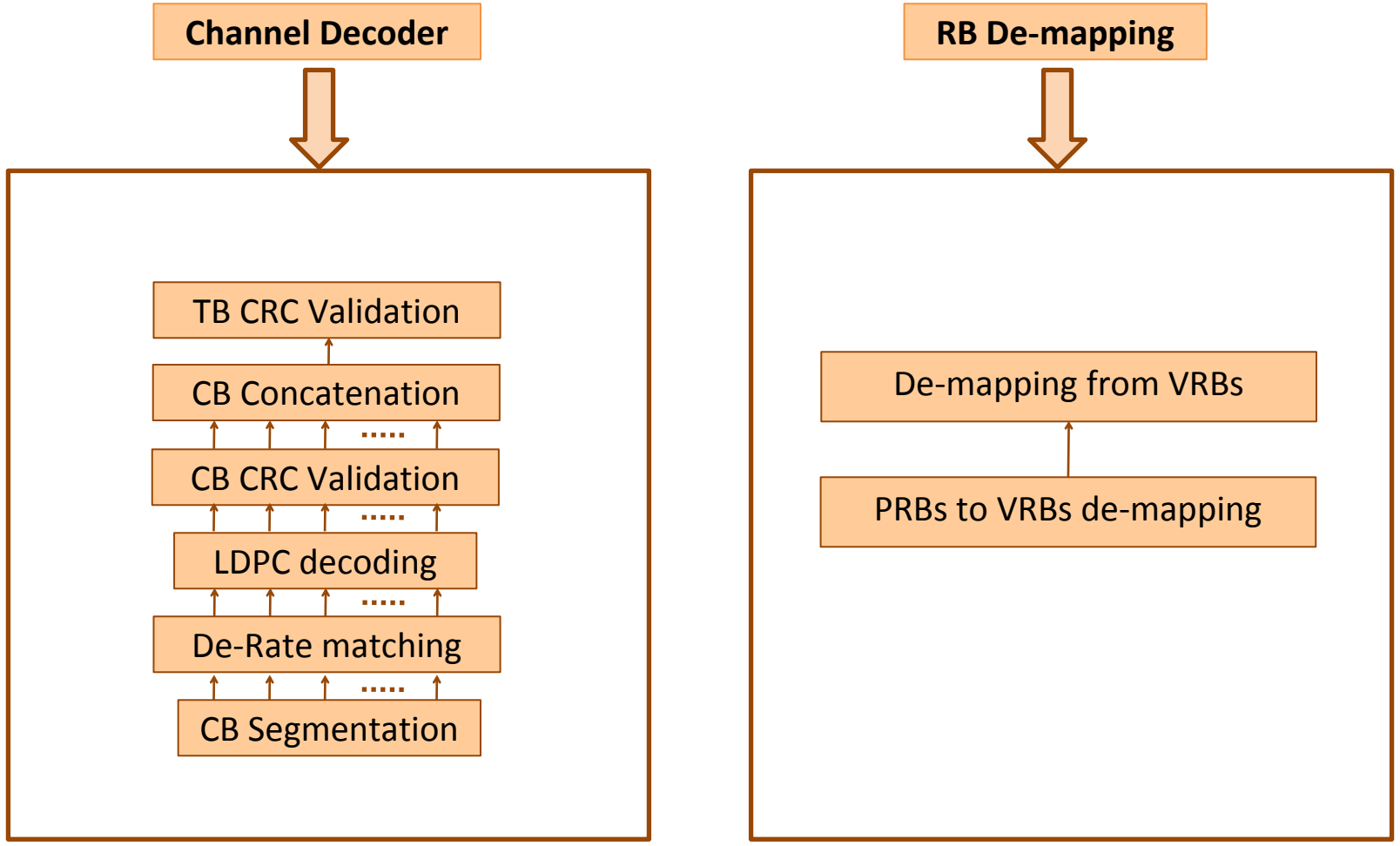
Receive Chain at UE



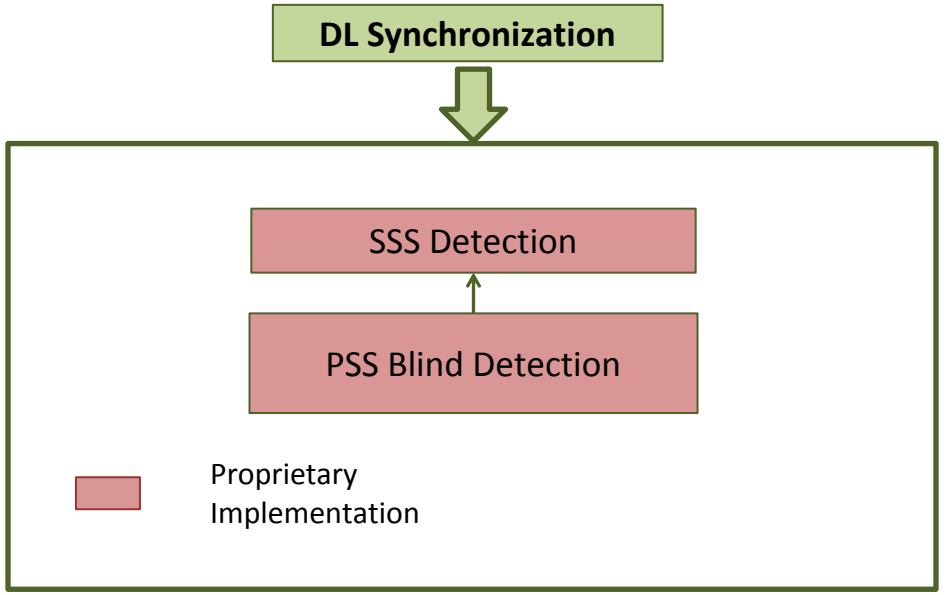
Channel Coding & RB Mapping



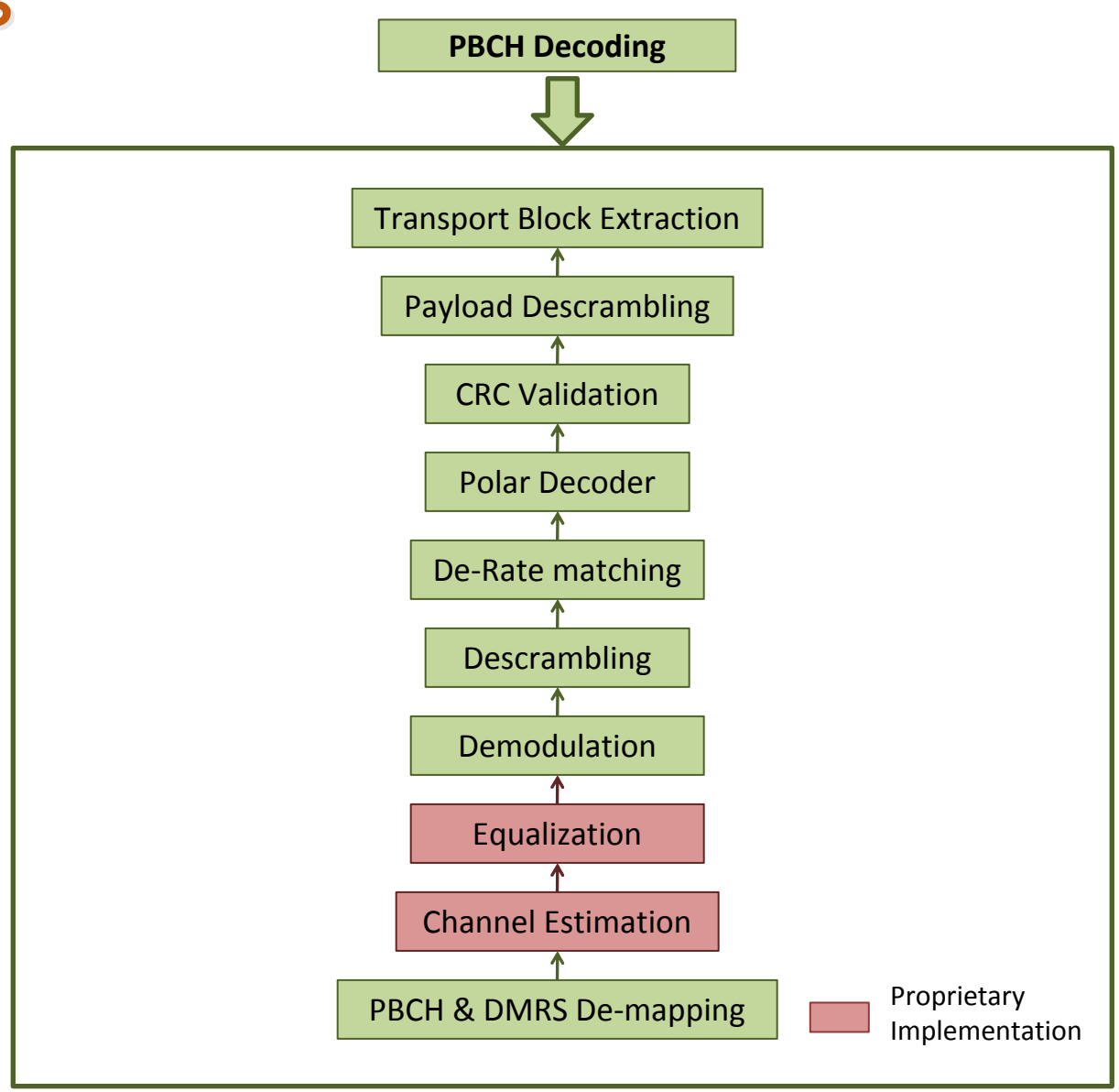
Channel Decoder & RB De-mapping



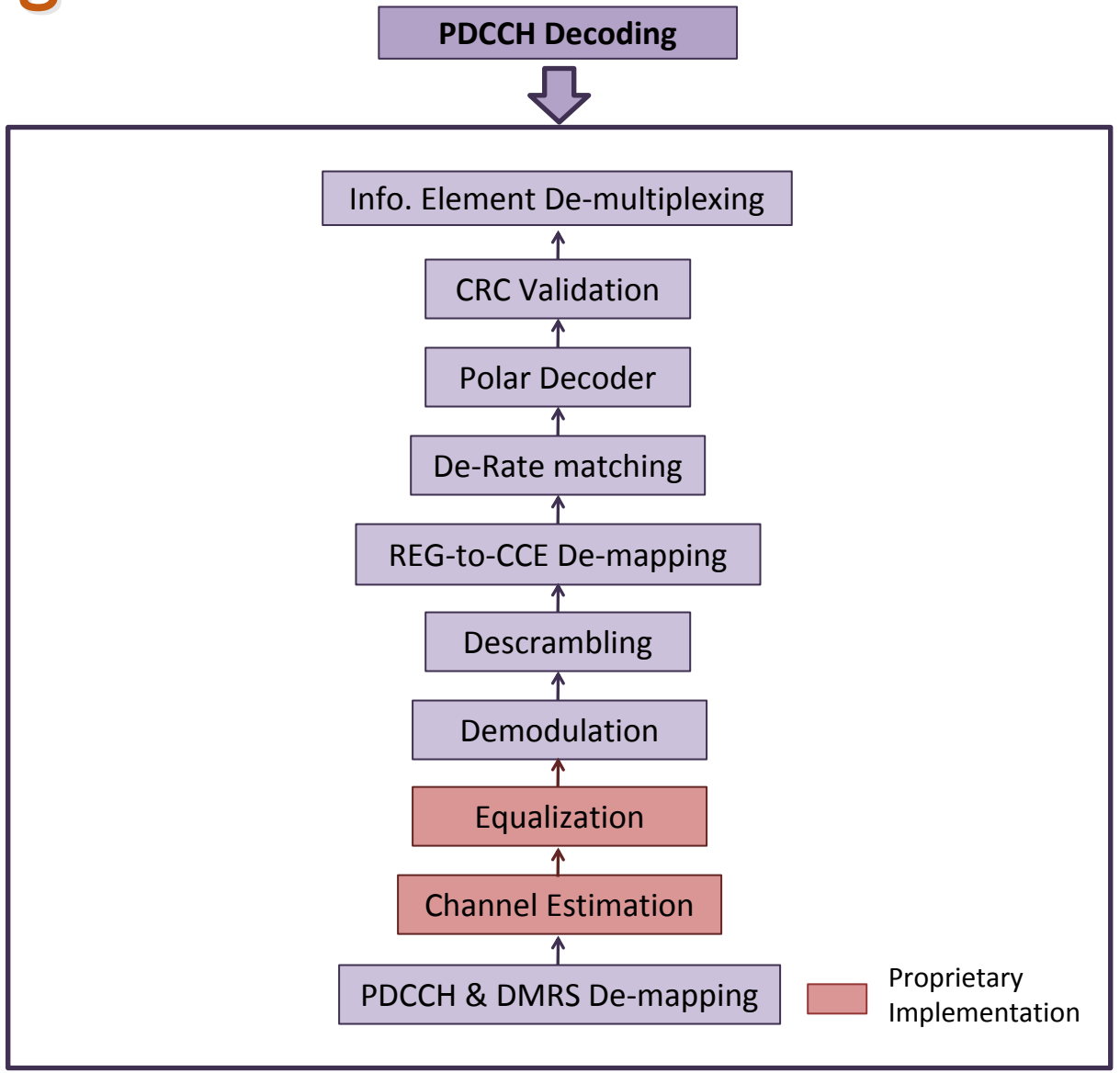
DL Synchronization



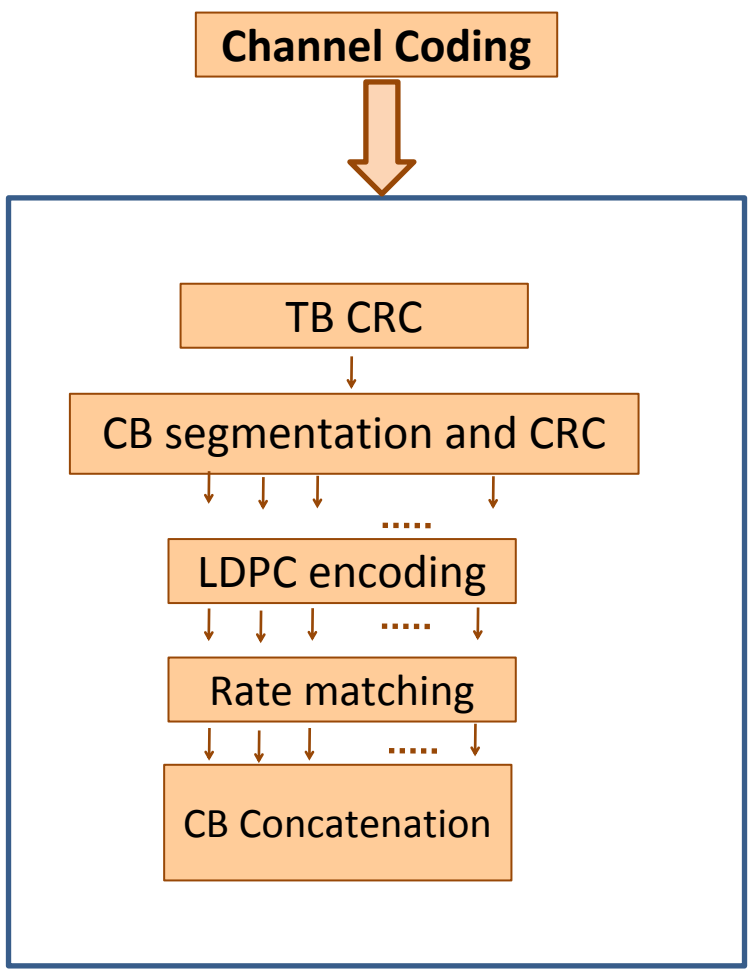
PBCH Decoding

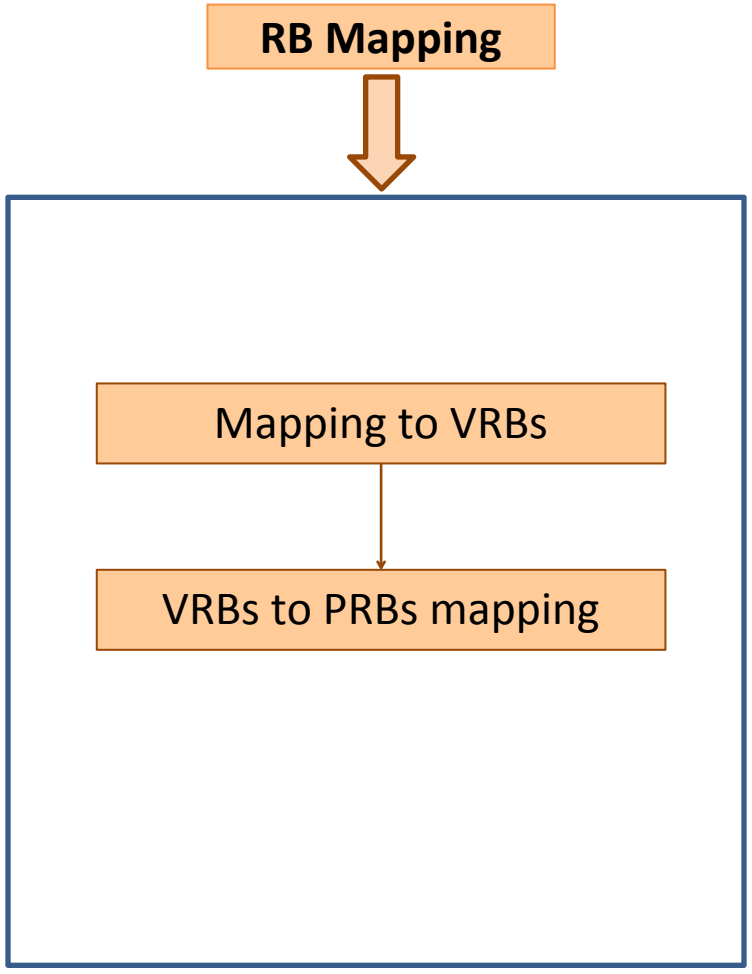


PDCCH Decoding

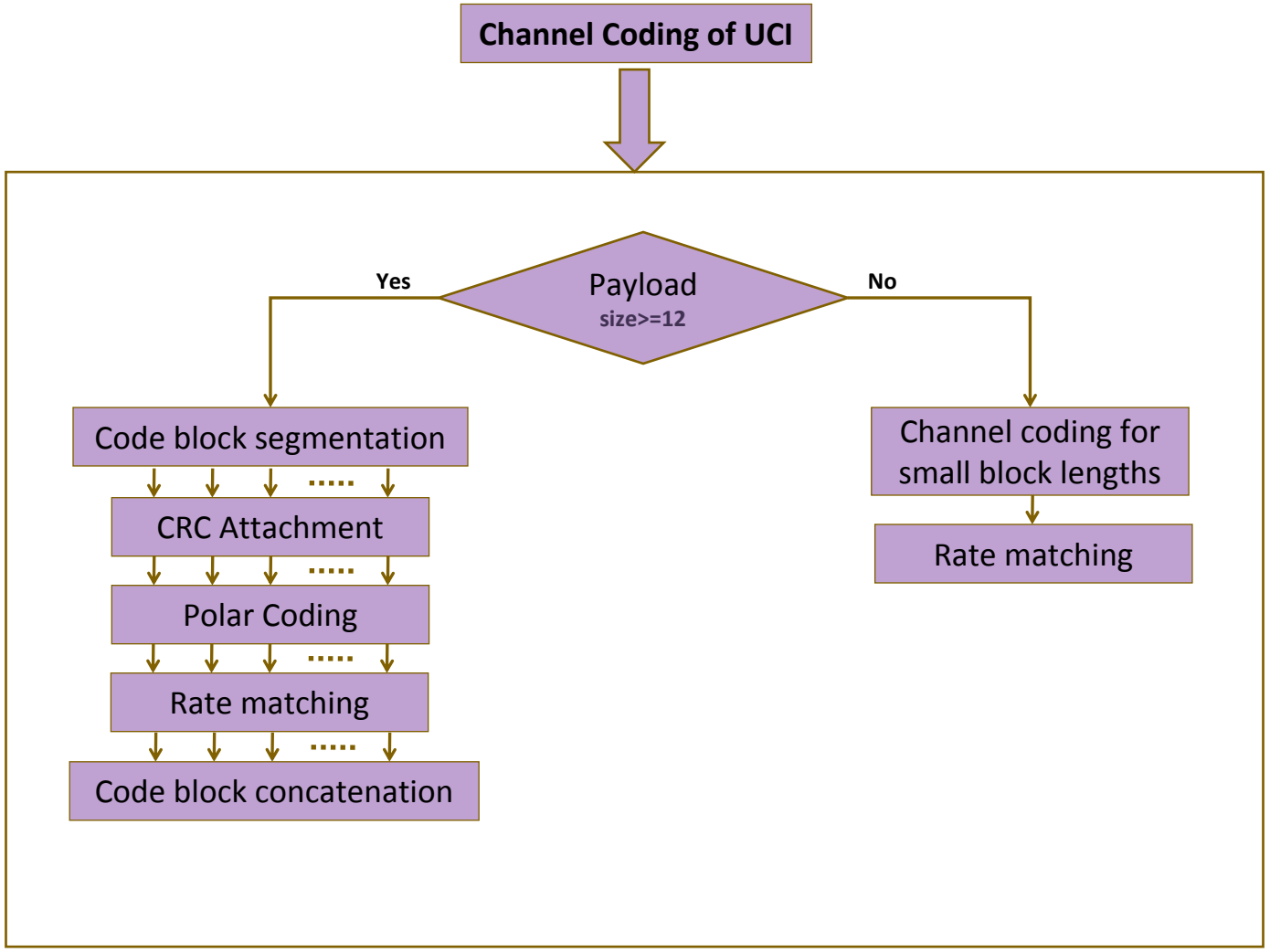


Channel Coding & RB Mapping

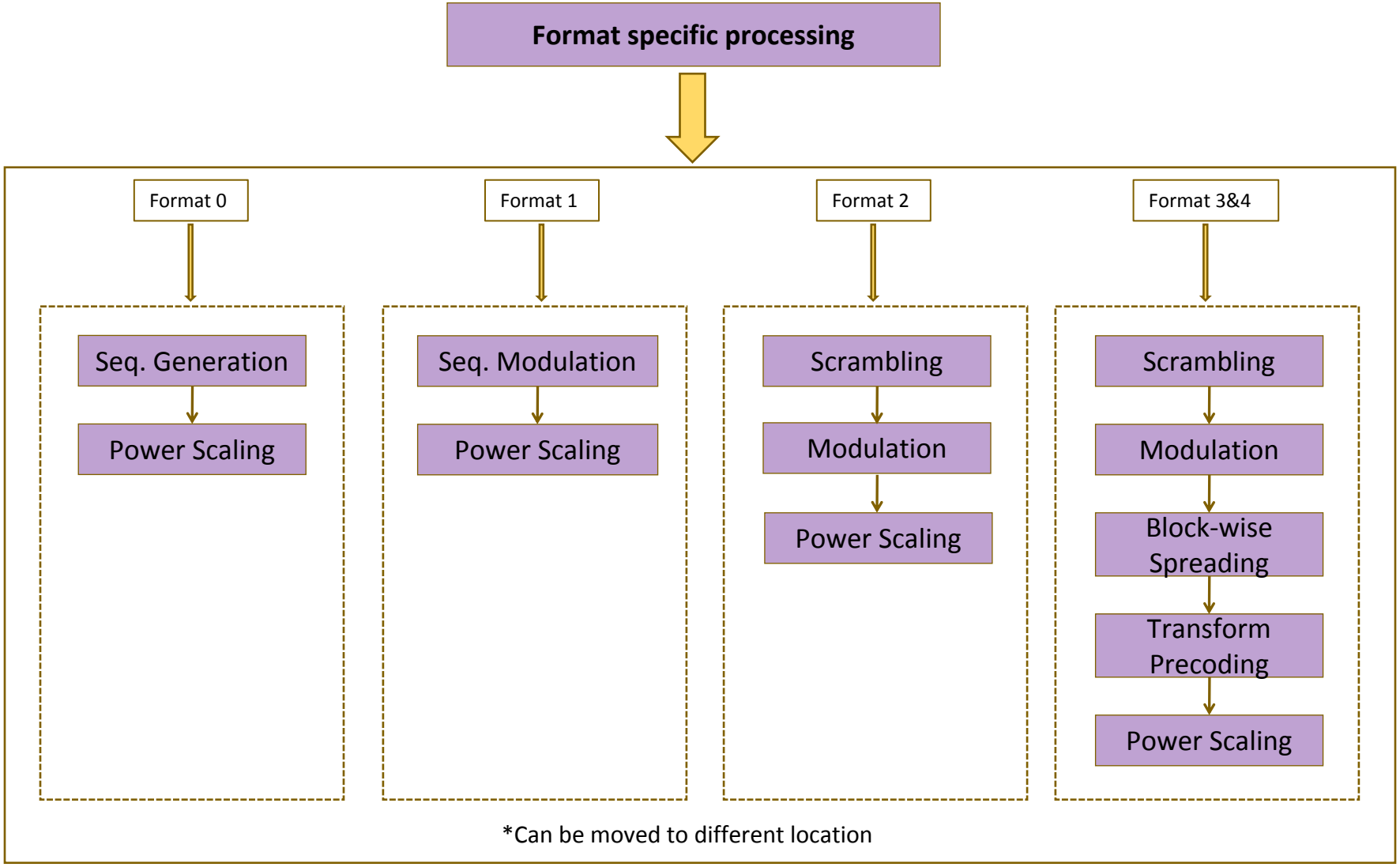




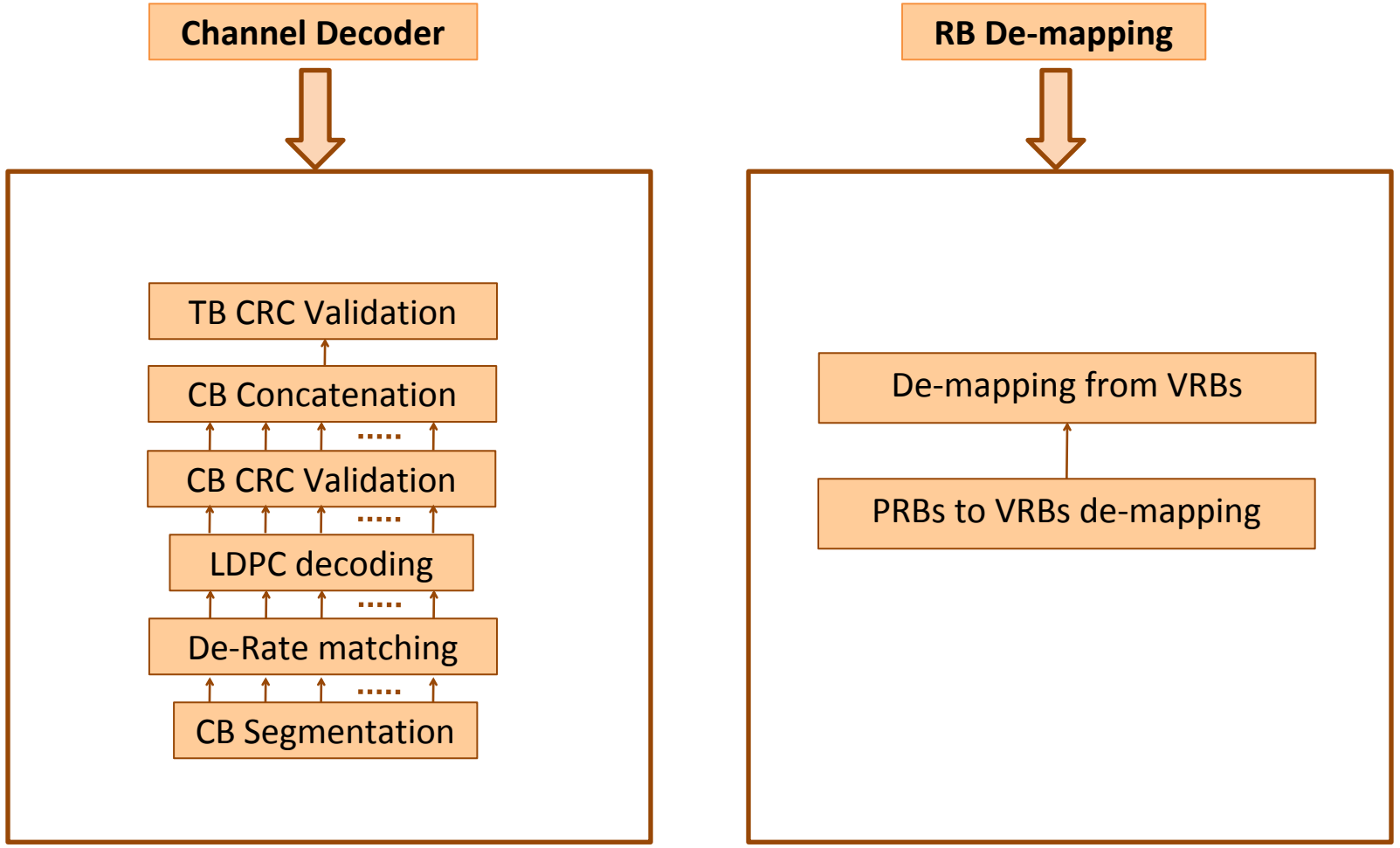
Channel Encoding of UCI



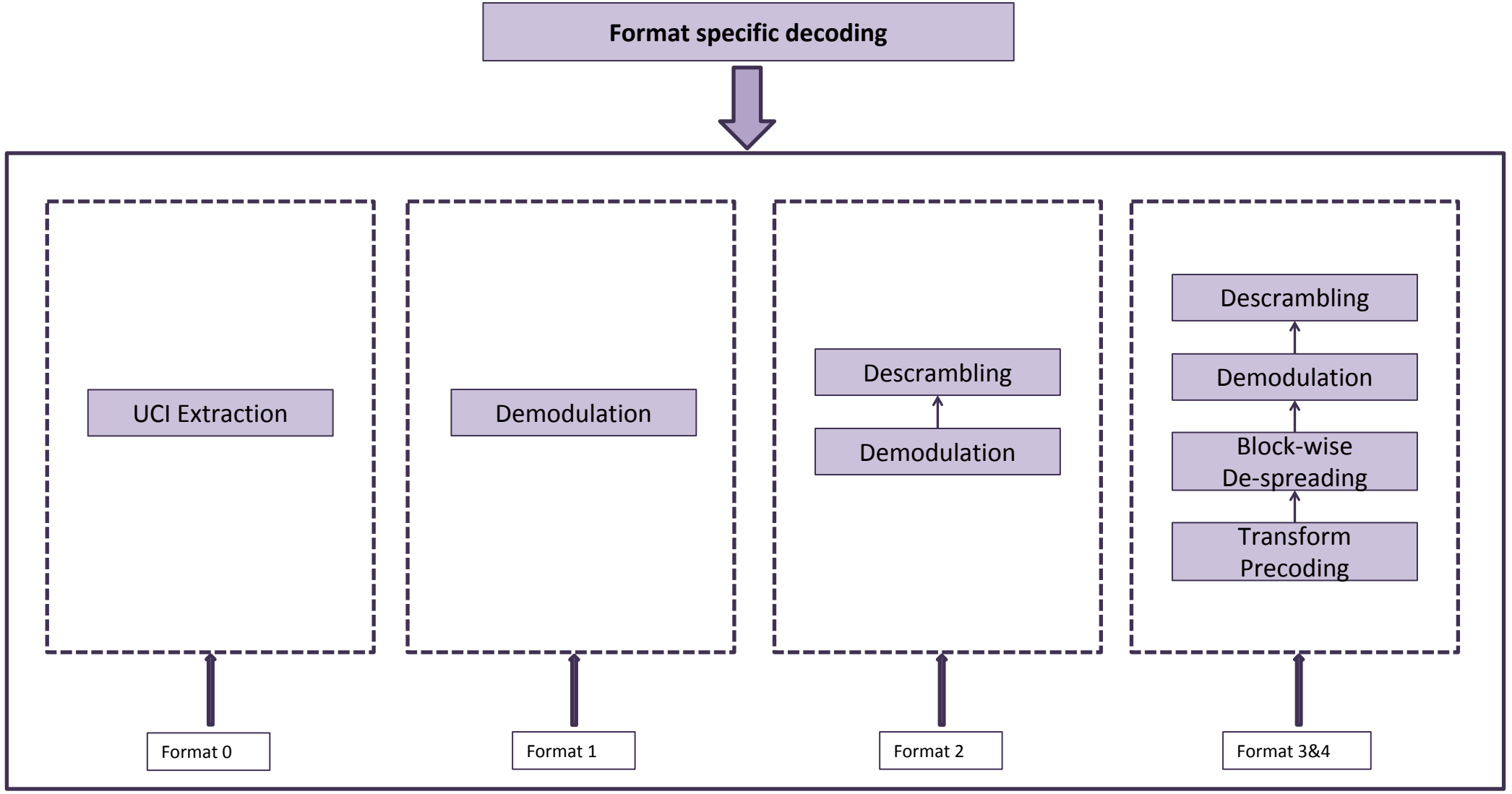
PUCCH Format Specific Processing



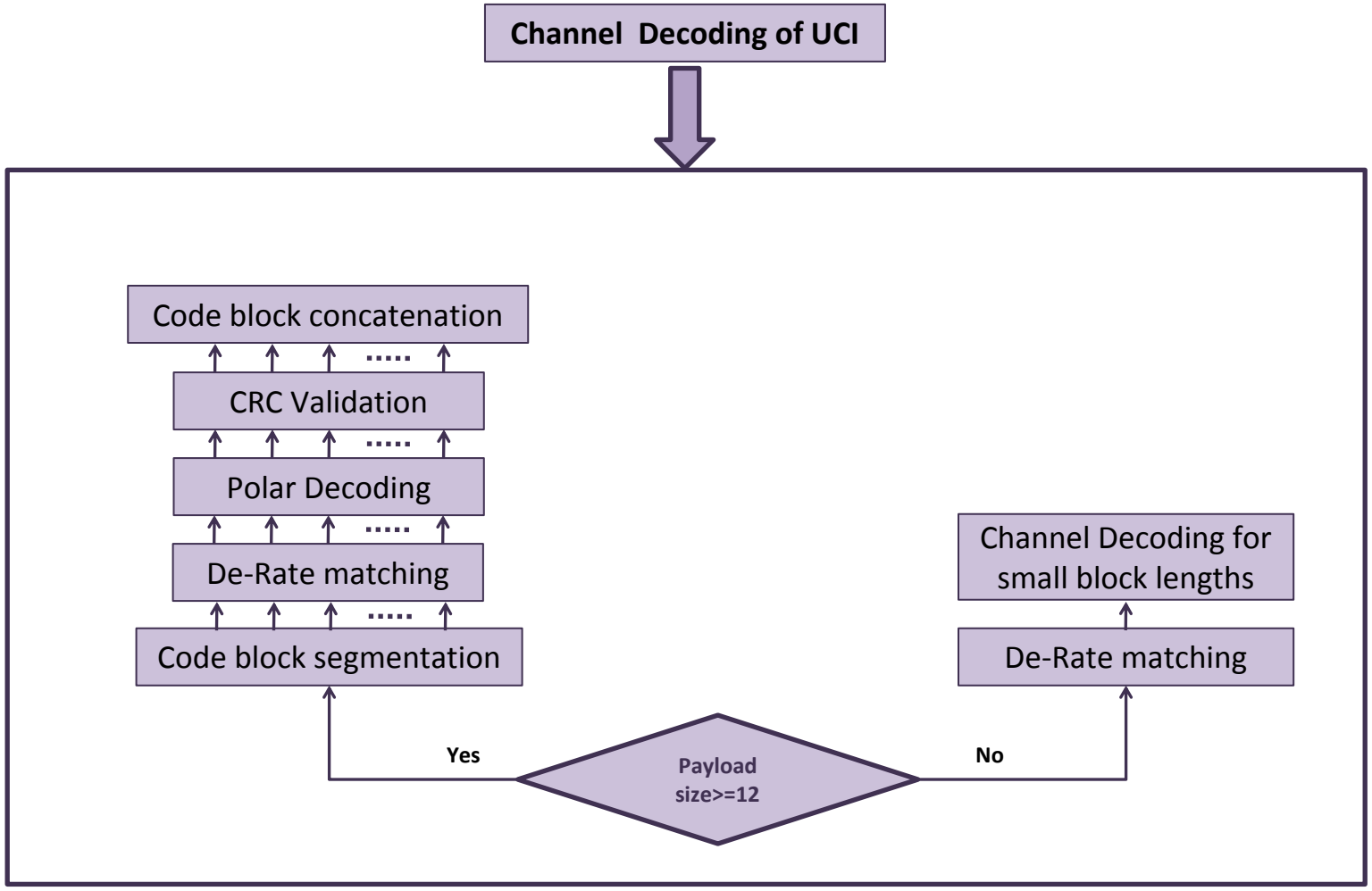
Channel Decoder & RB De-Mapping



PUCCH Format Specific Decoding



Channel Decoding of UCI



Thank You

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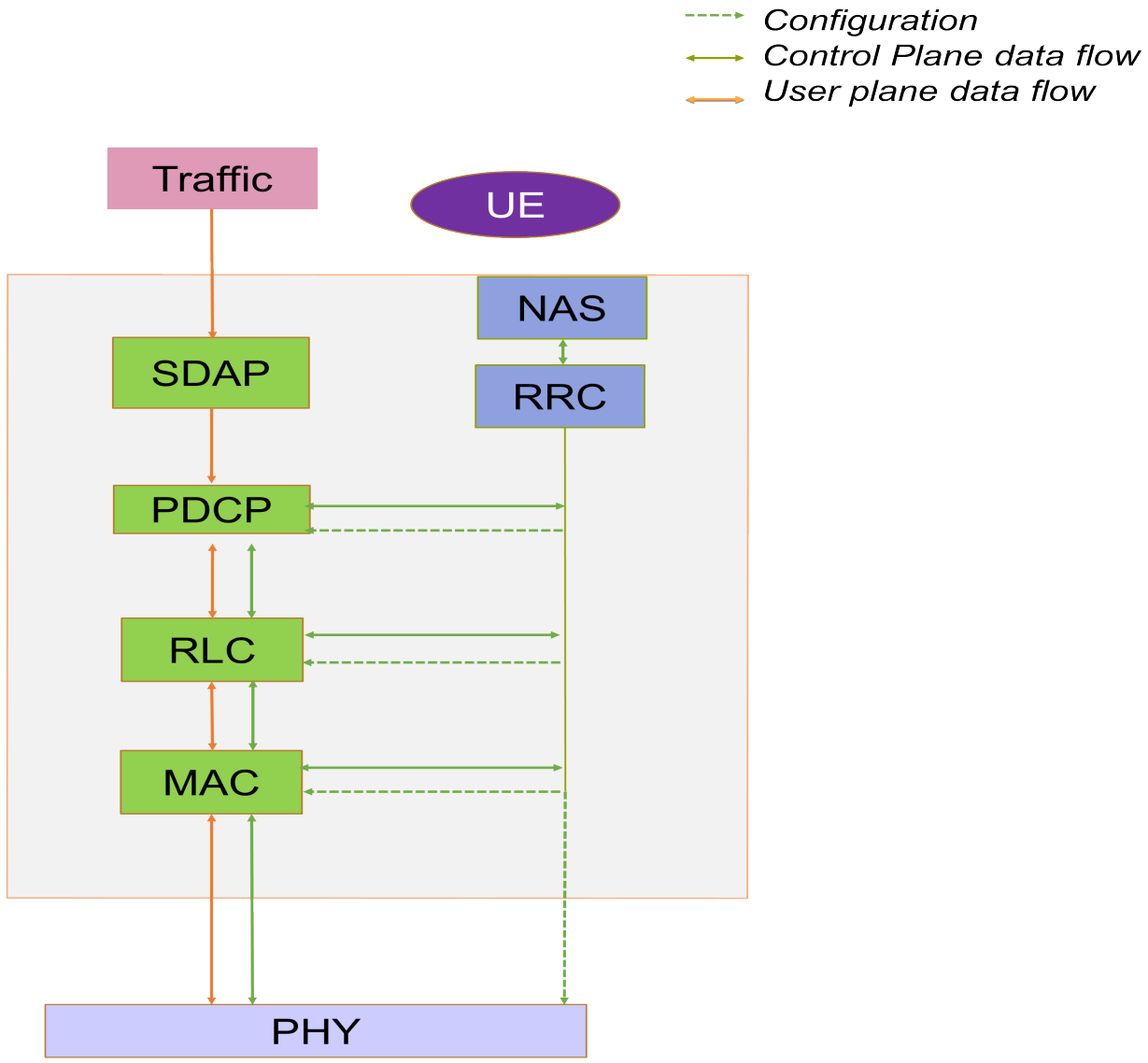
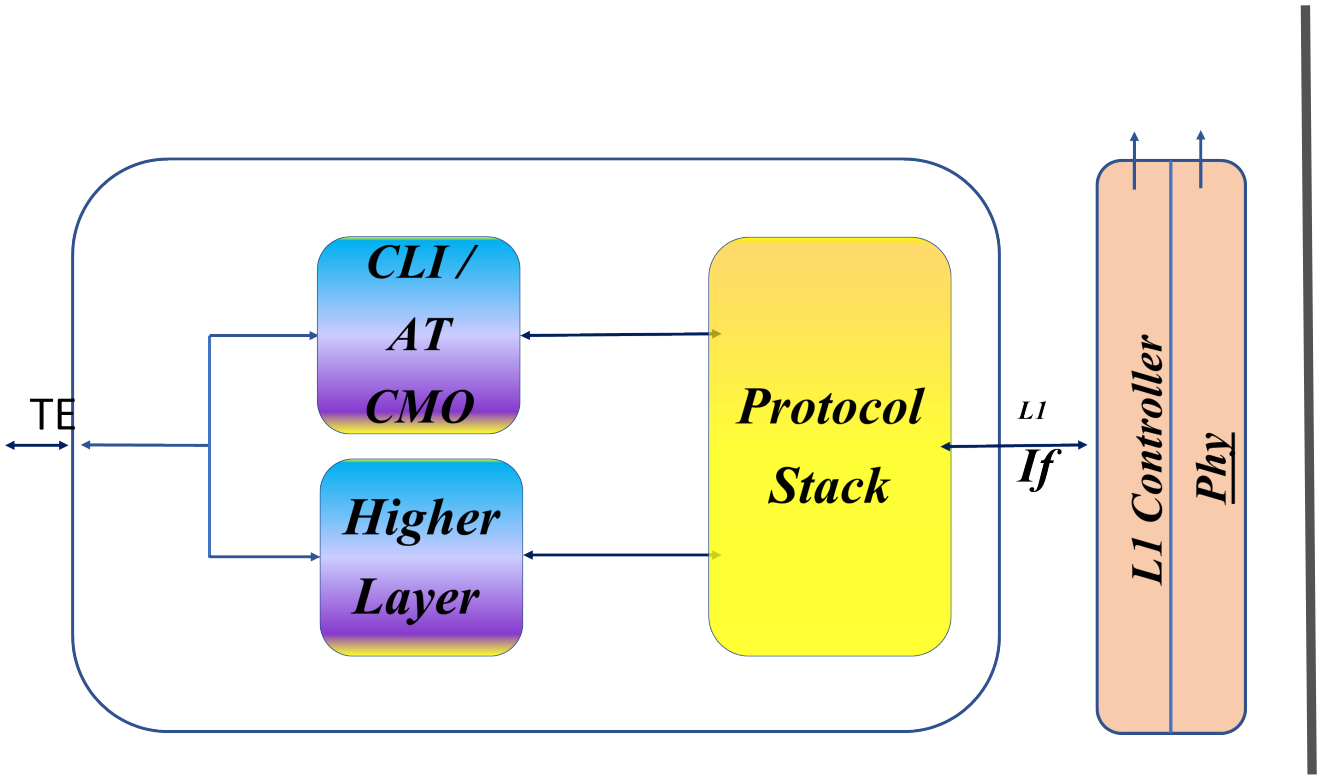
UE L2/L3 Stack
Developed by CEWiT in Collaboration with Lekha Wireless

L2/L3 Data Flow

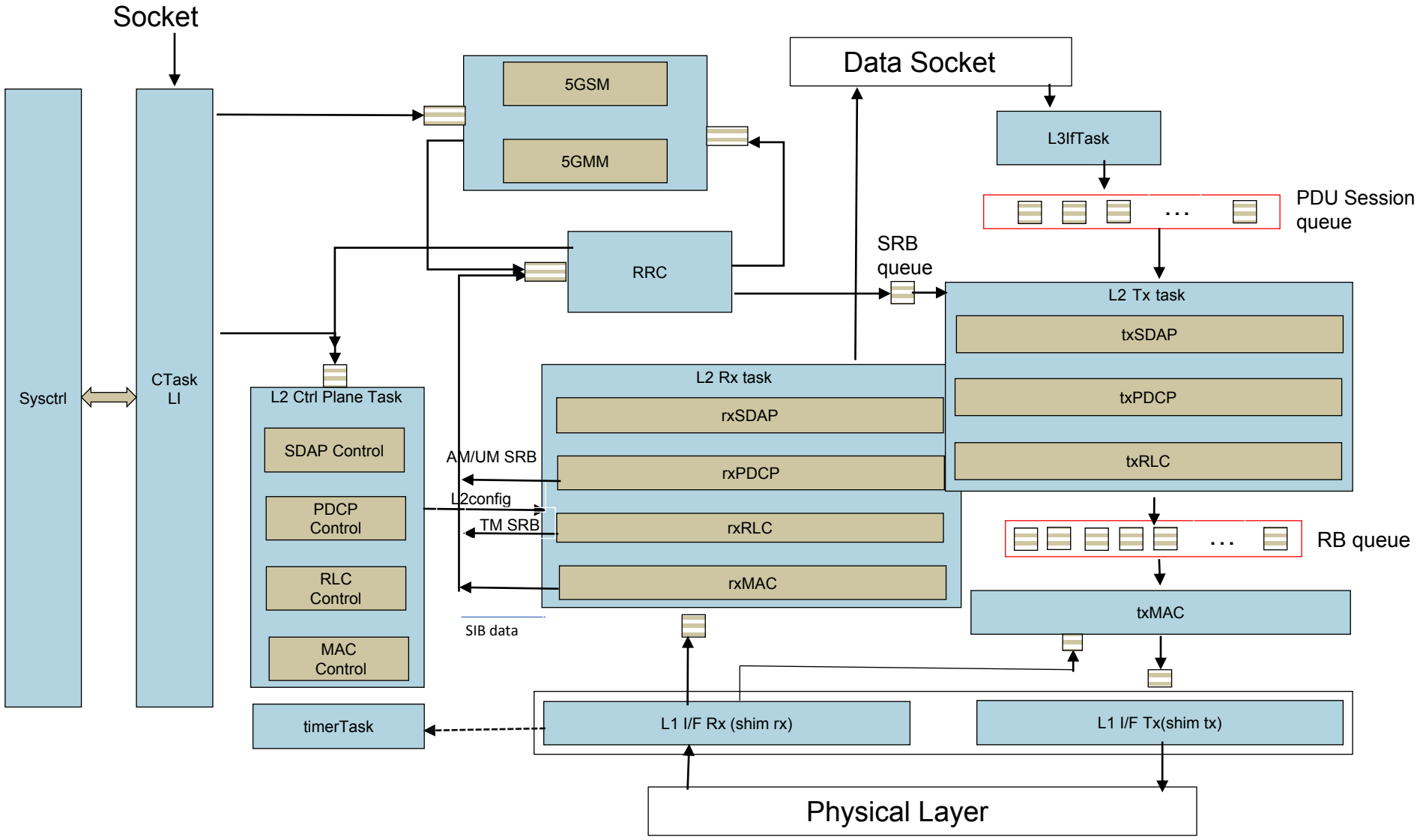


Software Architecture of UE L2 and L3



- Protocol stack
  - L2/L3 stack
- AT Command interpreter
  - Interacts with the protocol stack
- Higher Layer
  - UE Controller and Applications

Protocol Architecture



Logical Component Split Across Tasks

Task	Components
NAS Task	5GMM, 5GSM
RRC Task	RRC
Control Plane Task	L2 control interface
L3 If Data Task	L3 interface
L2 Transmitter Task	SDAP, PDCP, RLC
Transmitter MacTask	MAC
Receiver Task	MAC, RLC, PDCP, SDAP
Shim Transmitter Task	L1 interface
Shim Receiver Task	L1 interface
CLI Debug Task	Command Line Interface
System Control Task	System Control

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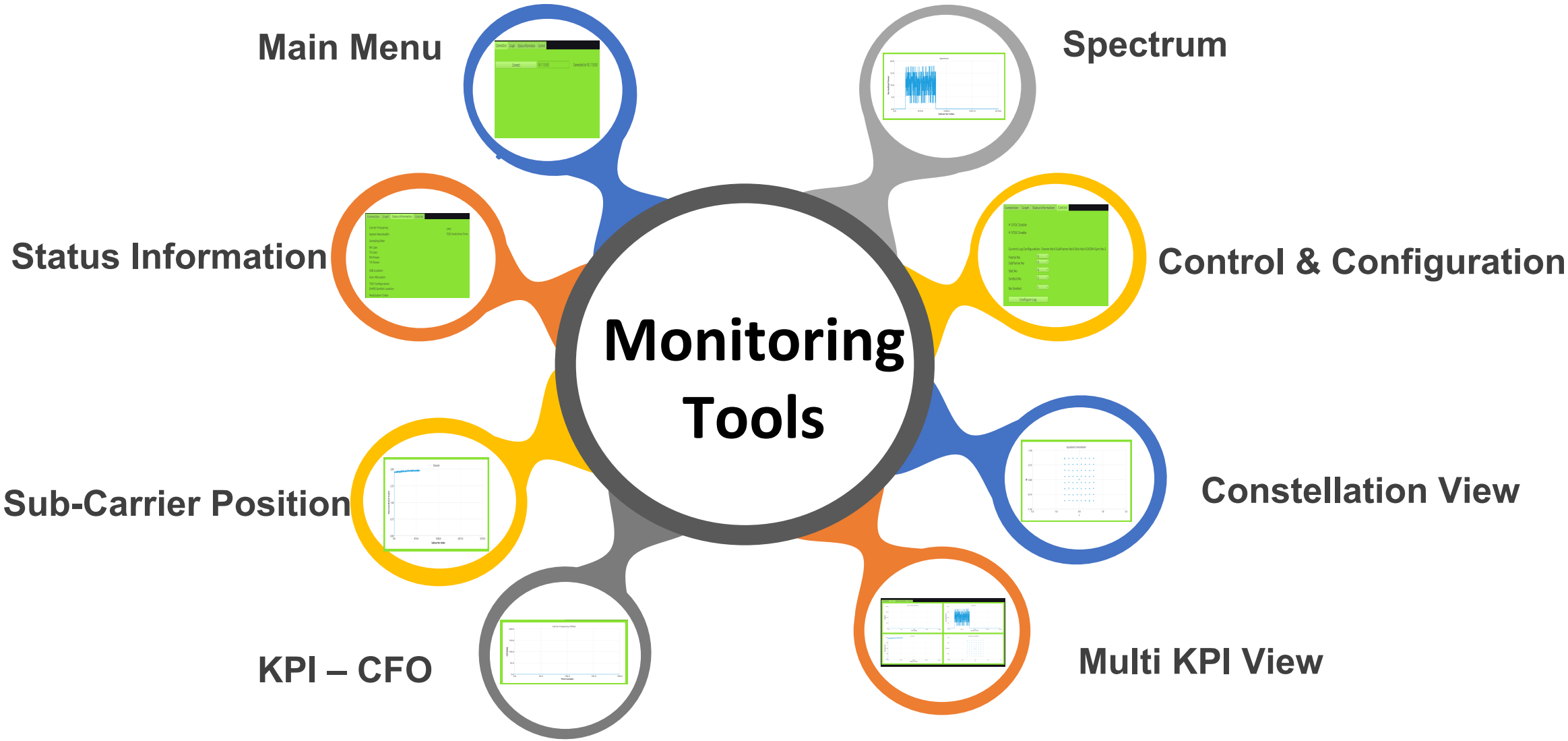
Control, Monitoring and Debugging

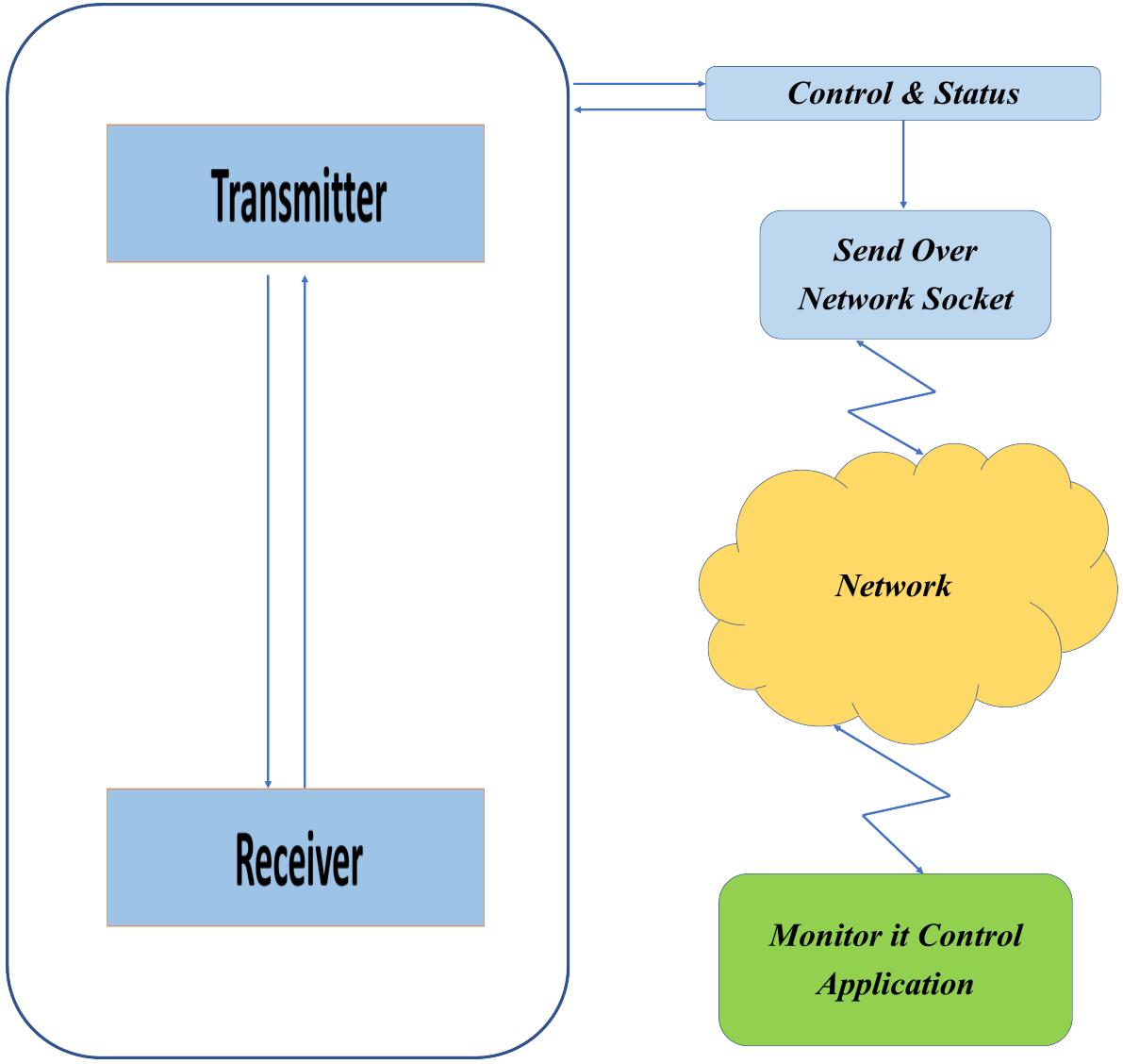
Developed by

CEWiT

Features Supported in the Tool



Architecture of the Tool



GUI Based Tool Applications

Control

- Enable/Disable functionalities in real time
- Adjusting Tx power, gain, etc

Monitoring

- Status Information
  - Power, Gain, Bandwidth, etc.
  - PSS Location, TDD Switching, CFO, etc.

Debugging

- Realtime view of various parameters
  - Identification of Impairments
  - Fixing the issues

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Interface to Plug & Play Algorithms Developed by CEWiT

Proprietary Algorithms Integration Points at gNB

Transmitter

- Between L2 and L1 – FAPI
  - Standard Interface
- Antenna Port Mapping – Precoder
  - As per specifications
- Reference Signal Configuration
  - Interface to be made available
- SSB Configuration
  - Interface to be made available
- Transmit Beam forming
  - Interface to be made available

Proprietary Algorithms Integration Points at gNB Receiver

- Between L1 and L2 – FAPI
  - Standard Interface
- Channel Estimation and Equalization
  - Interface to be made available
- CQI Computation
  - Interface to be made available
- Receive Beamforming
  - Interface to be made available
- Phase Noise Tracking
  - Interface to be made available

Proprietary Algorithms Integration Points at UE Transmitter

- Between L2 and L1 – Shim Interface
  - Command messages (MAC->PHY)
  - Response messages (PHY->MAC)
  - Mailbox messages (PHY->MAC)
- Precoder
  - As per specifications
- Reference Signal Configuration
  - Interface to be made available
- Transmit Beam forming
  - Interface to be made available

Proprietary Algorithms Integration Points at UE Receiver

- Between L1 and L2 – Shim Interface
  - Command messages (MAC->PHY)
  - Response messages (PHY->MAC)
  - Mailbox messages (PHY->MAC)
- Channel Estimation and Equalization
  - Interface to be made available
- CQI Computation
  - Interface to be made available
- Receive Beamforming
  - Interface to be made available
- Phase Noise Tracking
  - Interface to be made available

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5G Work

CEWiT

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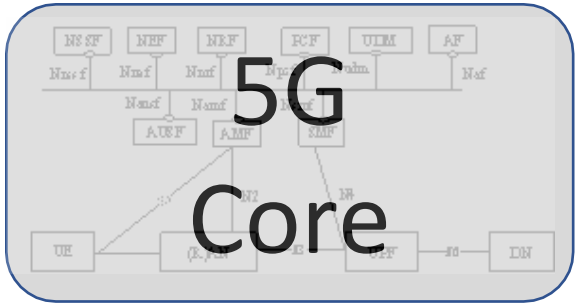
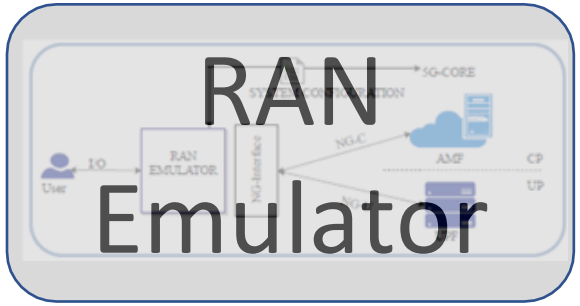
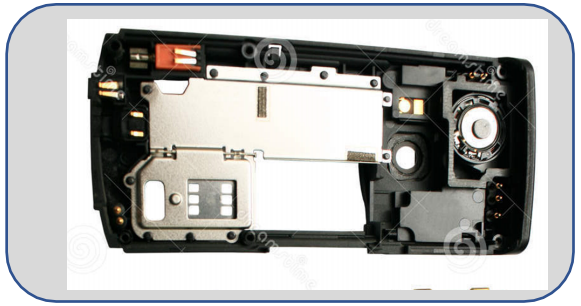
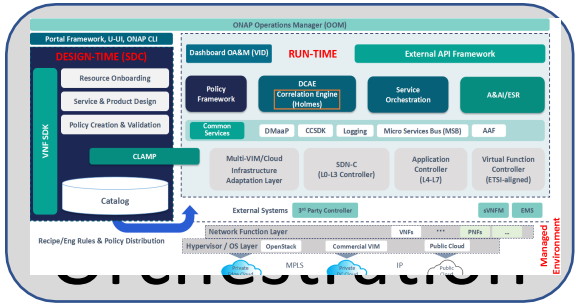
Core and Management Subsystems









SBA (Service Based Architecture) based 5G Core in the Indigenous 5G Test Bed

A collaborative effort from

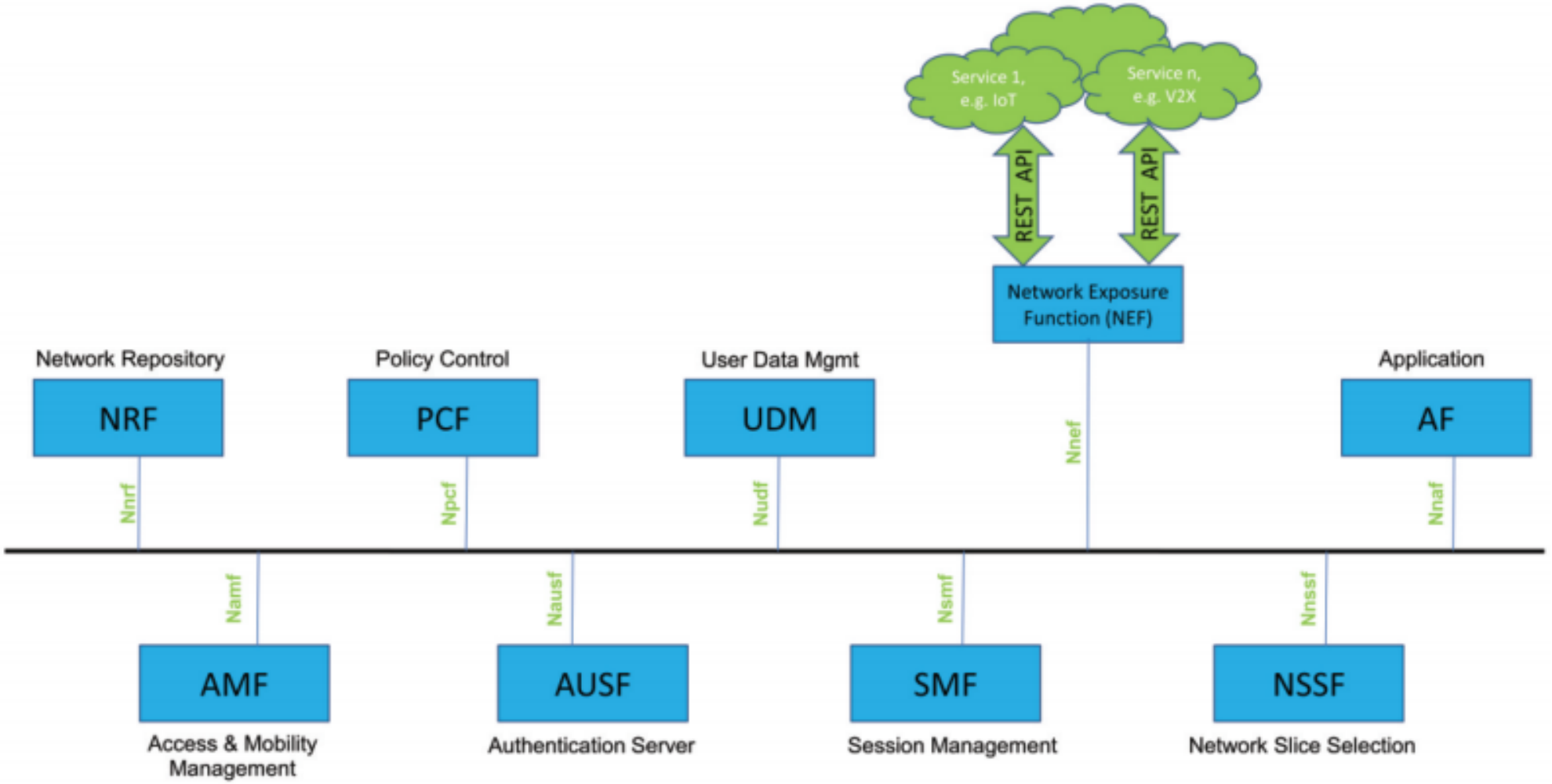
IITB

CEWiT INDIA

IITM

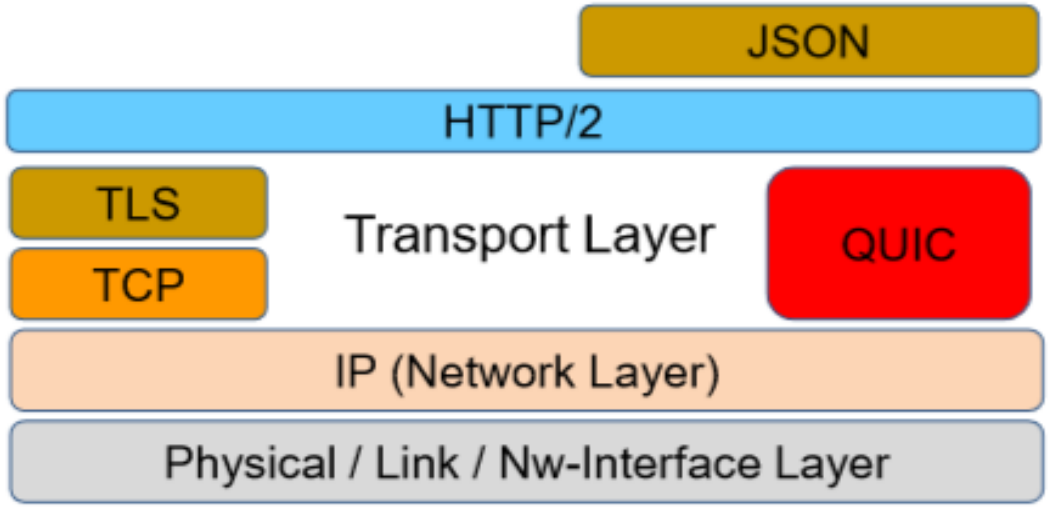
Details on 5G Core are also available in IIT Bombay presentation

5G Core designed with Service Based Architecture

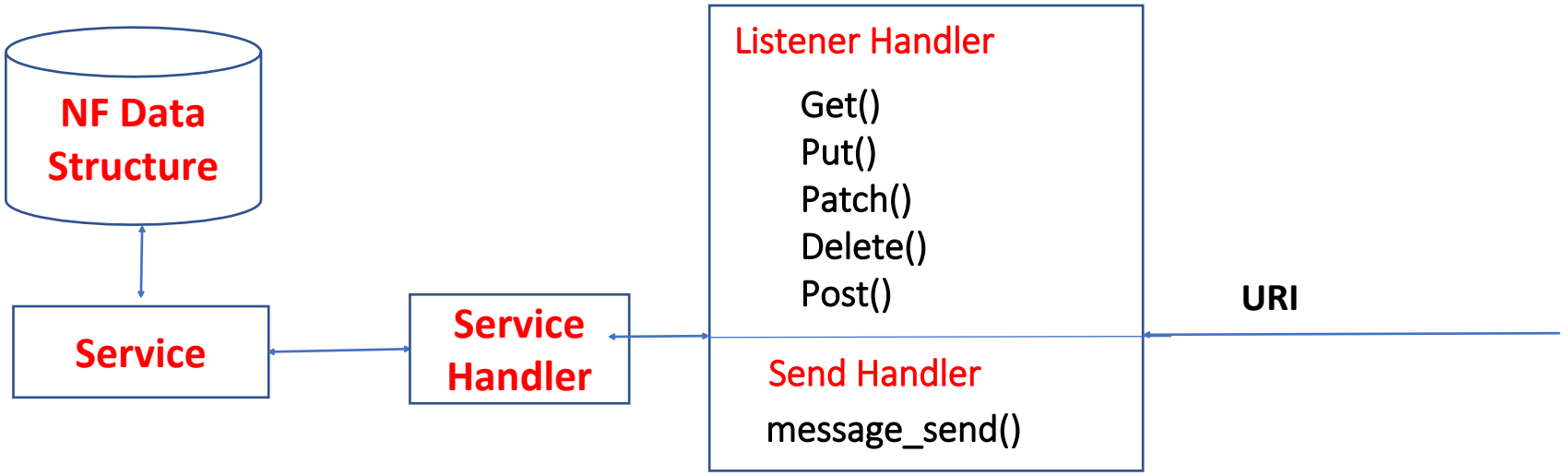


SBI Protocol Stack

- REpresentational State Transfer (REST) design paradigm is used.
- Interface Definition Language- OpenAPI 3.0
- HTTP/2 Protocol
- JSON - Serialization Protocol
- All 3GPP NFs support TLS.
- TLS used within a PLMN if network security not provided by other means.

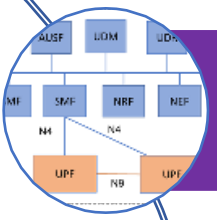


NF Implementation



Listener Handler	Listens to incoming HTTP message and invokes the corresponding HTTP handler. Extract the path, query and json data and pass it to corresponding NF service handler.
Send Handler	Will send the HTTP request message to the NF producer.
Service Handler	Intermediate function to extract the parameters & map json to corresponding service structure and pass it to service function. Similarly parse structure to json and send it to corresponding NF.
Service	Services as defined by 3GPP
NF Data Structure	NF profile and other Service data structure. Local storage repository of each NF.

Solid Outcomes of the 5G Core Activities



5G Core network Functions

NAS Stack

NG

NGAP Stack

UE Higher layers framework

- **Flexible License models**
- **Option of Source Code licensing**

Thank You

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Click for CEWiT Main Menu 

Click for Project Main Menu 

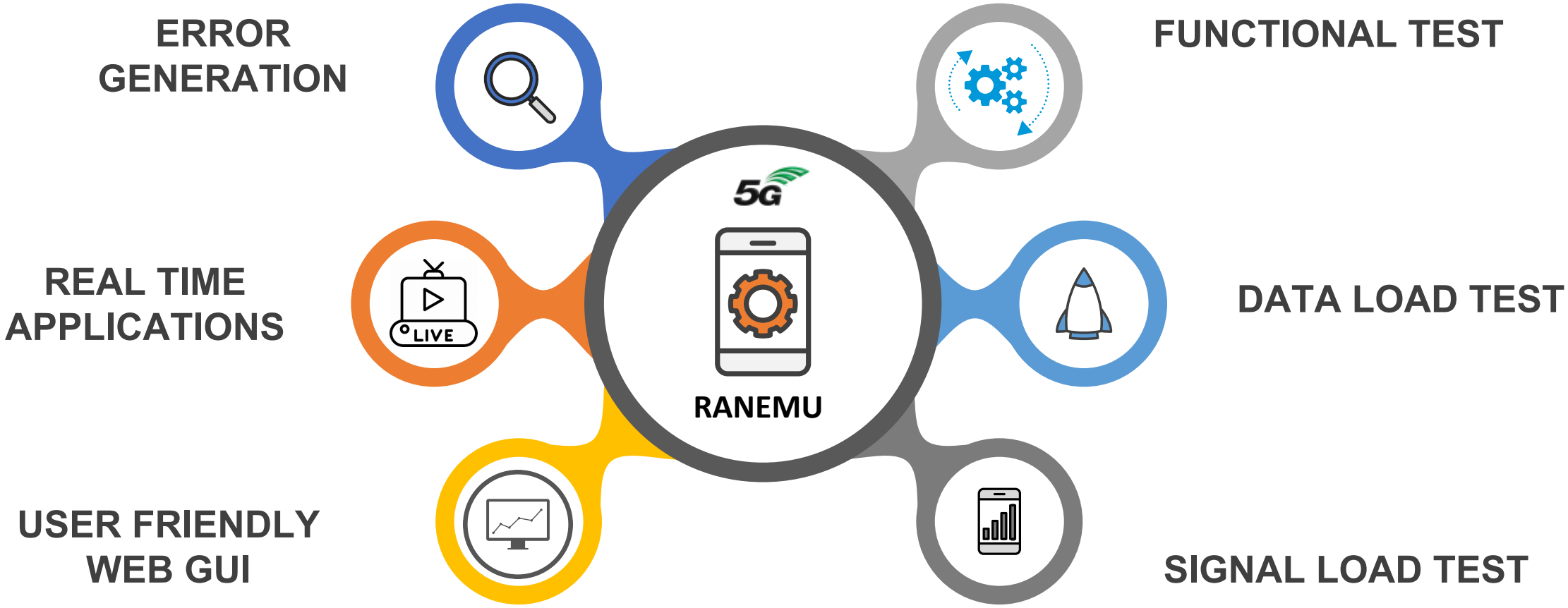
An extensive and versatile

RAN EMULATOR

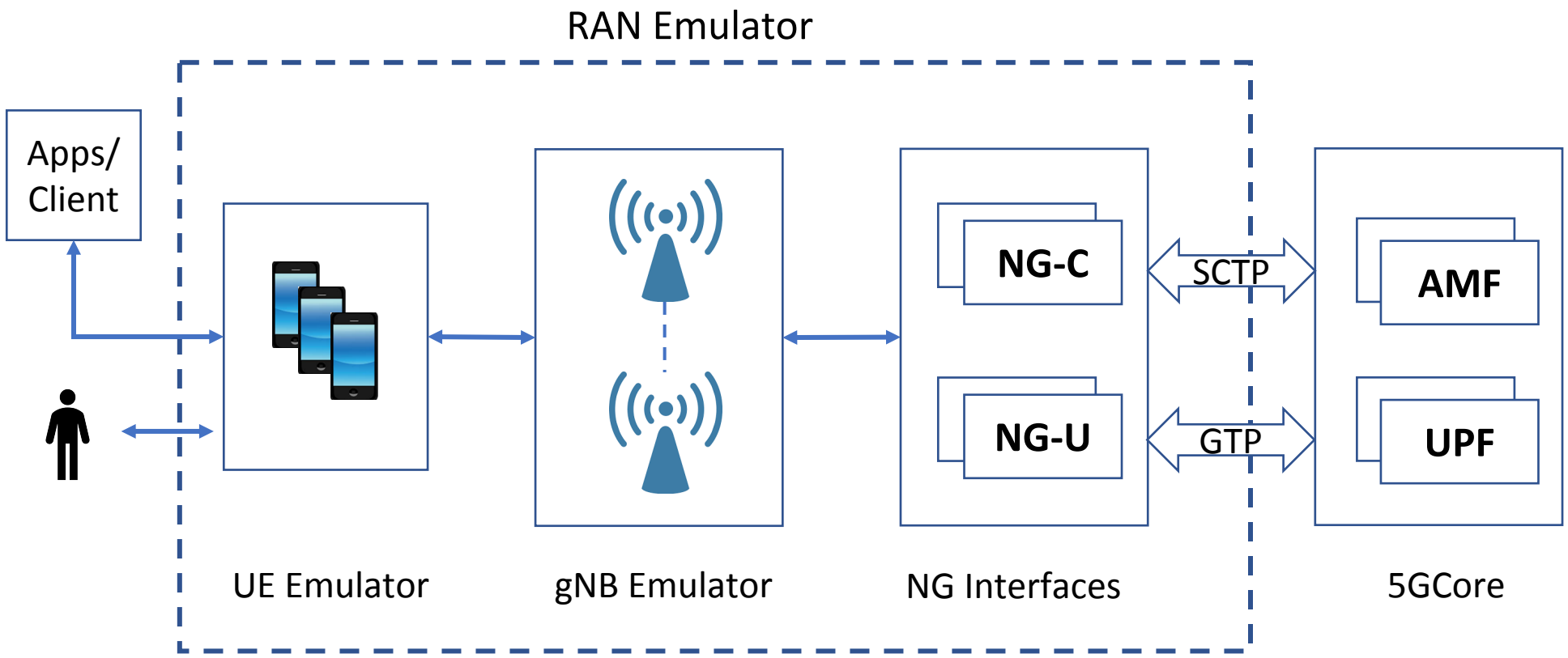
for

Advanced 5G Network Testing

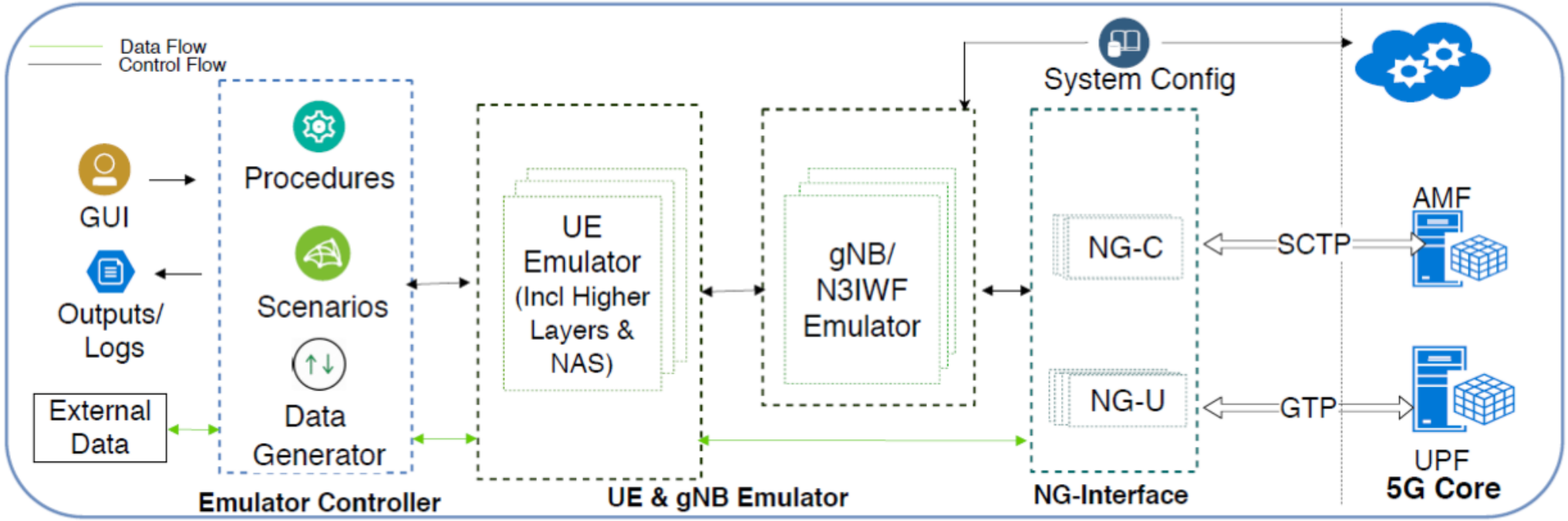
Features supported by RAN Emulator



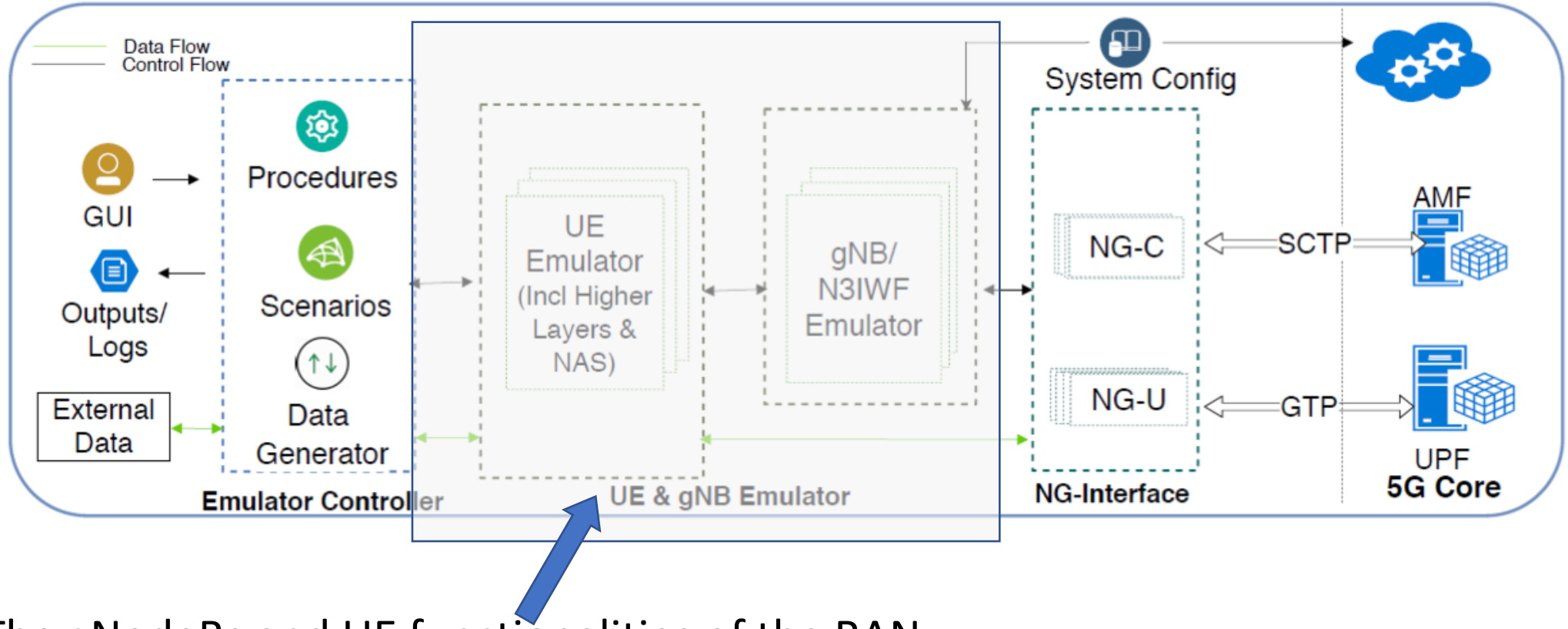
RAN Emulator



The Architecture of RAN Emulator

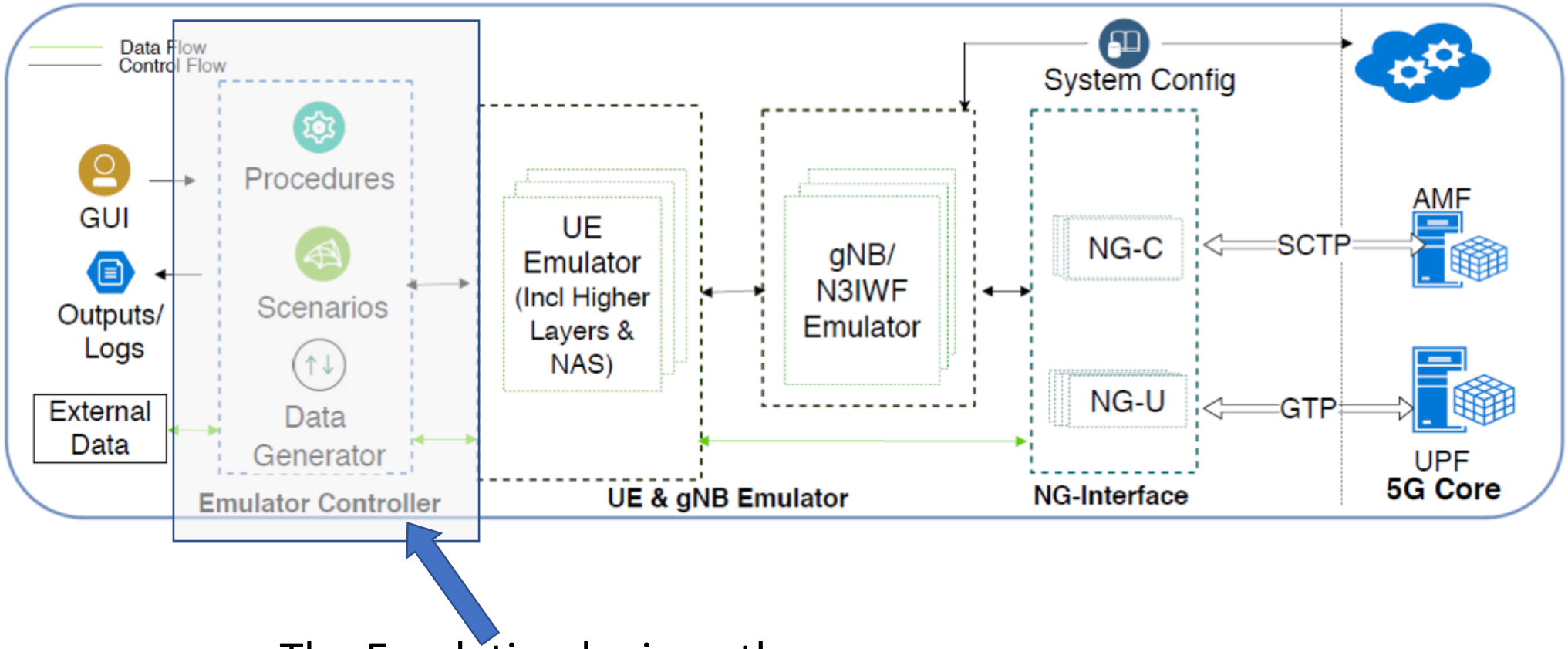


The Architecture of RAN Emulator



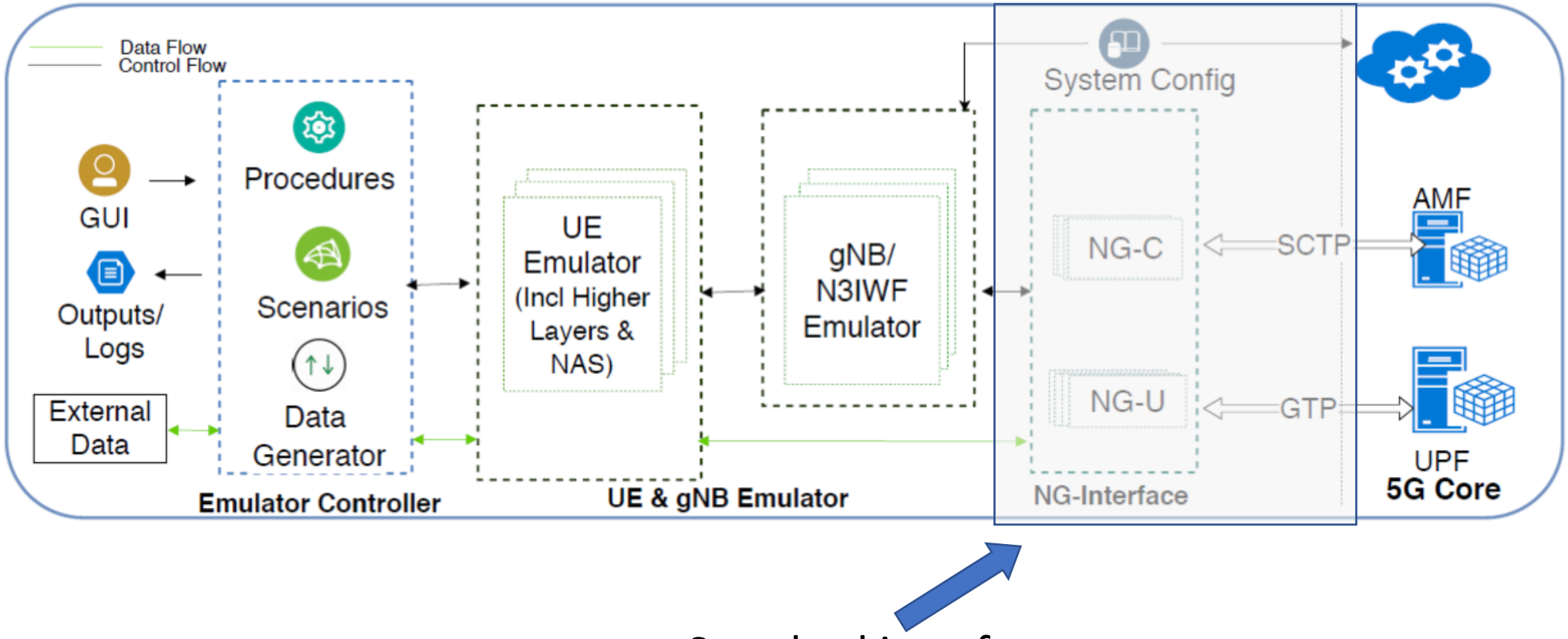
The gNodeBs and UE functionalities of the RAN are emulated here with full functionality of NAS and NG Stacks

The Architecture of RAN Emulator



The Emulation logic or the test logic is executed here

The Architecture of RAN Emulator



Standard interfaces are
provided towards the 5G Core

RAN Emulator can help various type of 5G activities!

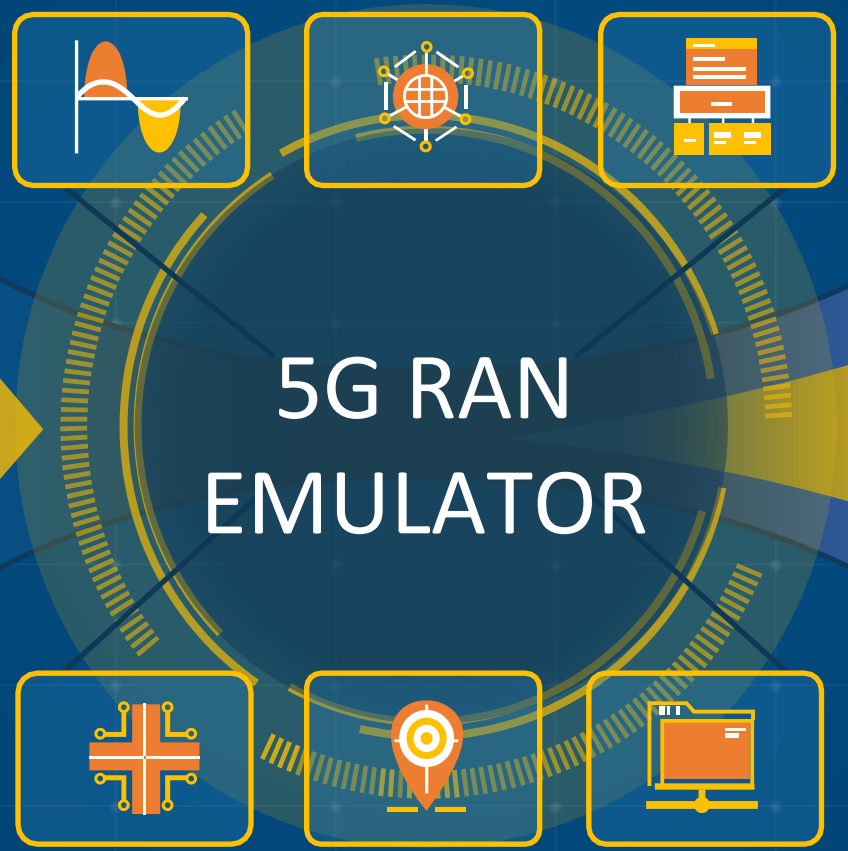
TESTS SUPPORTED

- PROCEDURE TEST
- SCENARIO TEST
- DATA LOAD TEST
- SIGNAL LOAD TEST
- RT APPLICATION TEST

Signal Load Analysis

Traffic Flow Test

NF Validation



UE/gNB Integration

Data Load Analysis

NAS/NG Stack Validation

USERS

- 5G Core Dev/Testers
- Students/Research Scholars
- 5G Full Stack Dev/Testers
- 5G Application Dev/Testers
- Stack Vendors

Versatility of RAMEMU

Procedure Test

- Provision to test individual procedures.
  - Ex. Registration of 1000 UEs
- Each procedure triggered manually or automatically through test configuration

Scenario Test

- Facility to test a complete scenario -
  - A set of procedures, Abnormal situations with Managed timings
  - Ex. Register 200 UEs, 100 to establish PDU Sessions, Video data for 50 UEs, IOT data for 3 UEs, 100 deregister and so on.

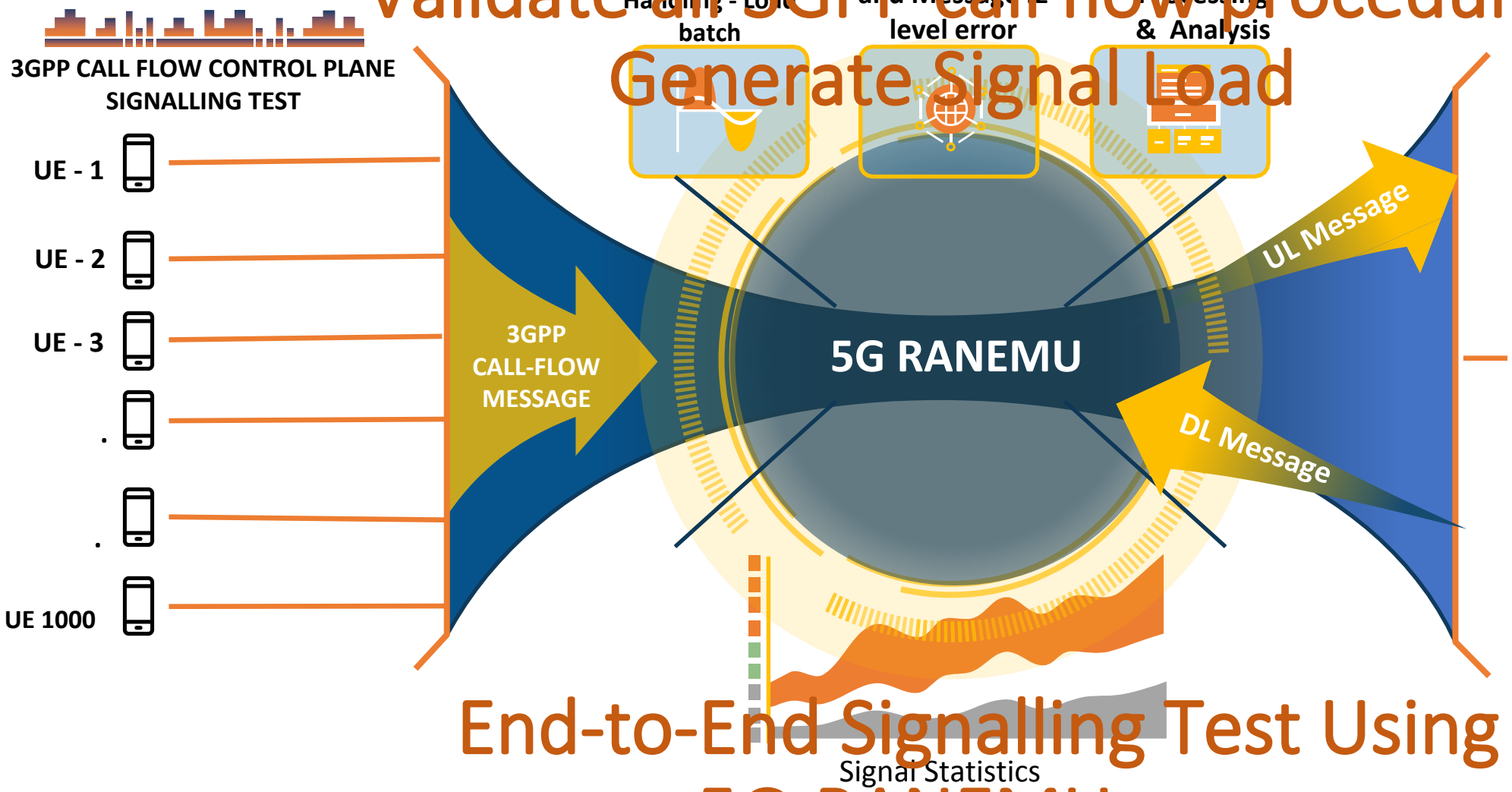
PROCEDURE TEST

CEWiT INDIA

SIGNALLING LOAD TEST

Validate all 3GPP call flow procedure

Generate Signal Load

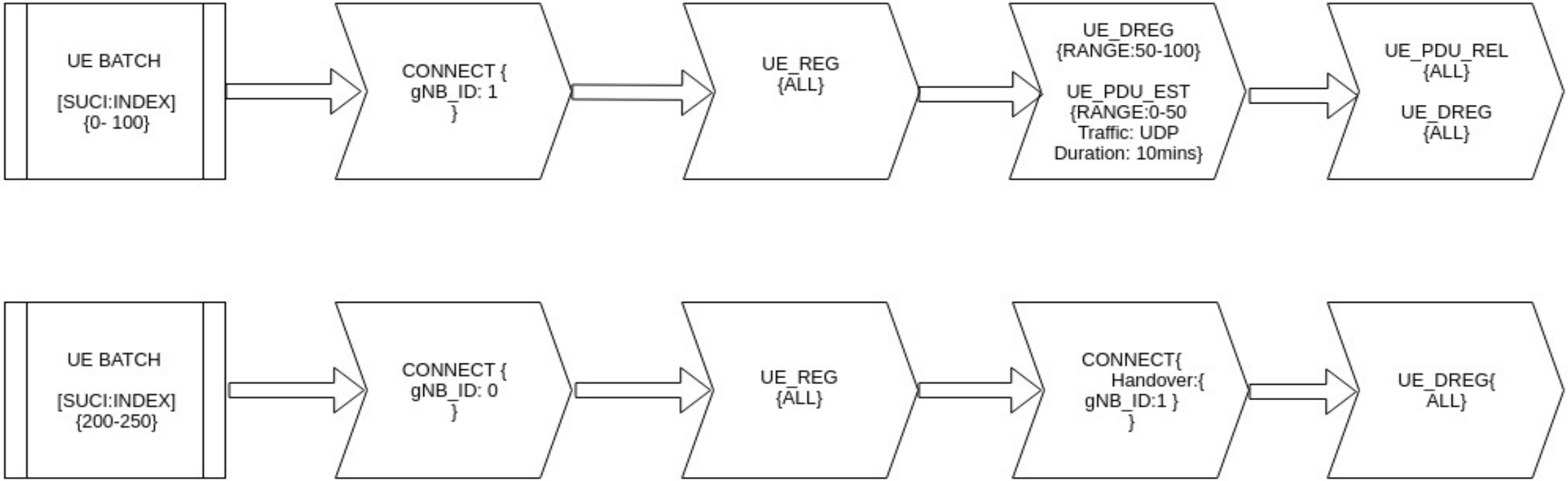


End-to-End Signalling Test Using 5G-RANEMU

SCENARIO TEST

A set of Procedures, Abnormal situations with managed timings

Define your own Test scenario



RANEMU provides a GUI that is simple and easy to use

5G RANEMU

ABOUT HELP SUPPORT

CONFIGURATION

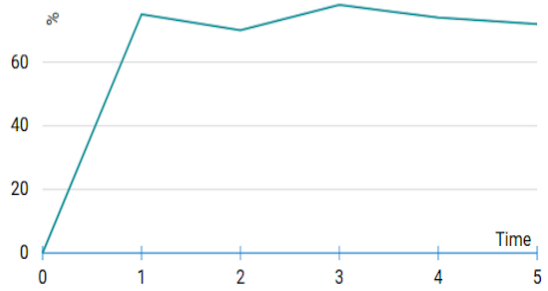
Emulation Setup
General

Streaming Client — 1 gNB — 5G Core Network — Video Server

Real Time Application Test Running

Video Streaming
Real Time Application Test

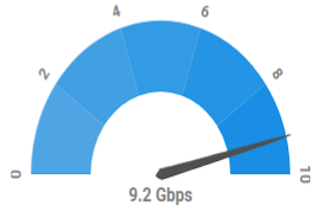
CPU Utilisation
General



Signaling Load Statistics
Signaling Load Test

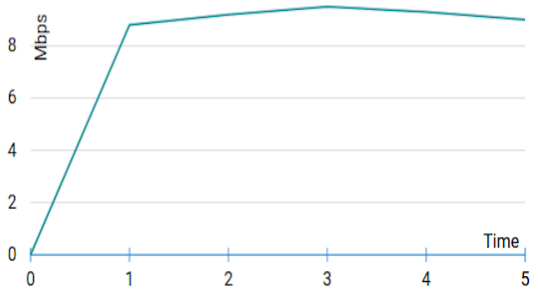
Total number of UE initiated	10000
Number of UE successfully completed the procedure test	10000
Number of UE failed procedure test	0
Time for one UE registration(ms)	82
Avg signal latency(us)	289
UPF throughput(Gbps)	9.13

Speed Test
Data Load Test



UE Throughput
Data Load Test

Select UE: UE_1



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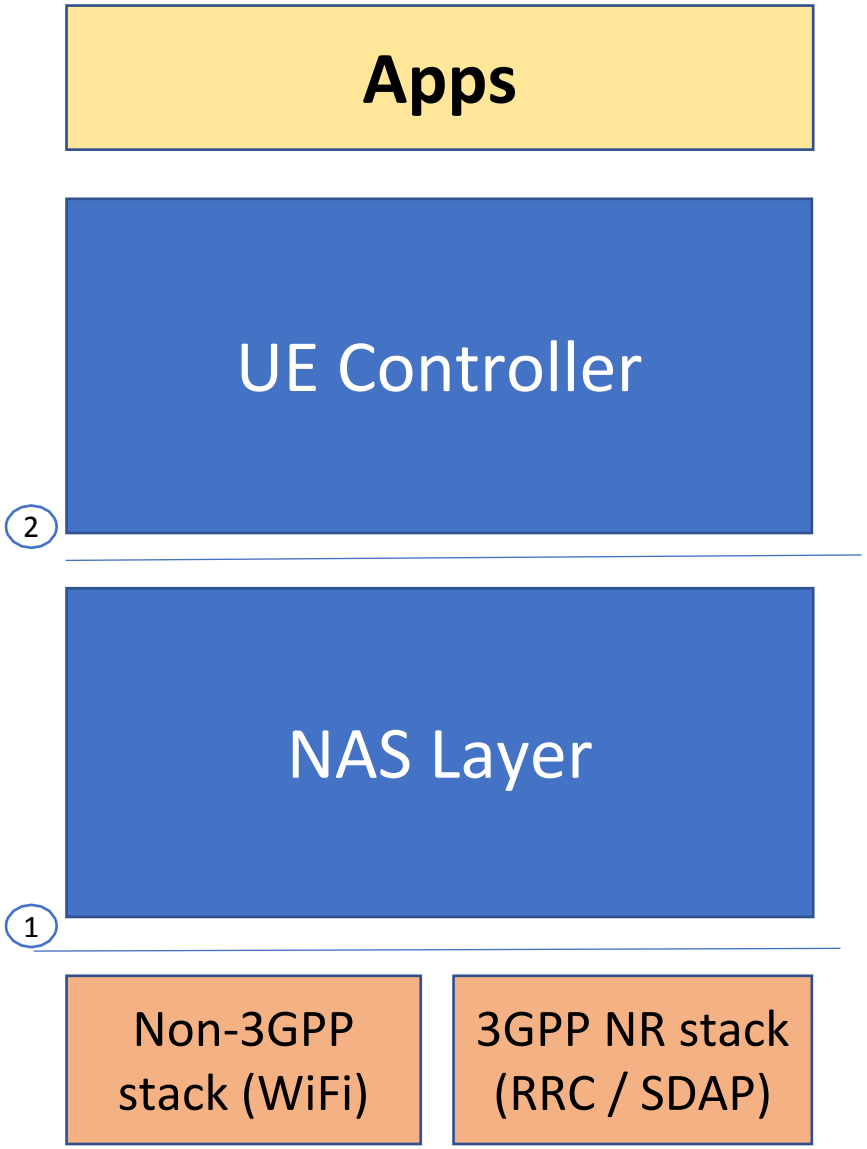
Click for CEWiT Main Menu

Click for Project Main Menu

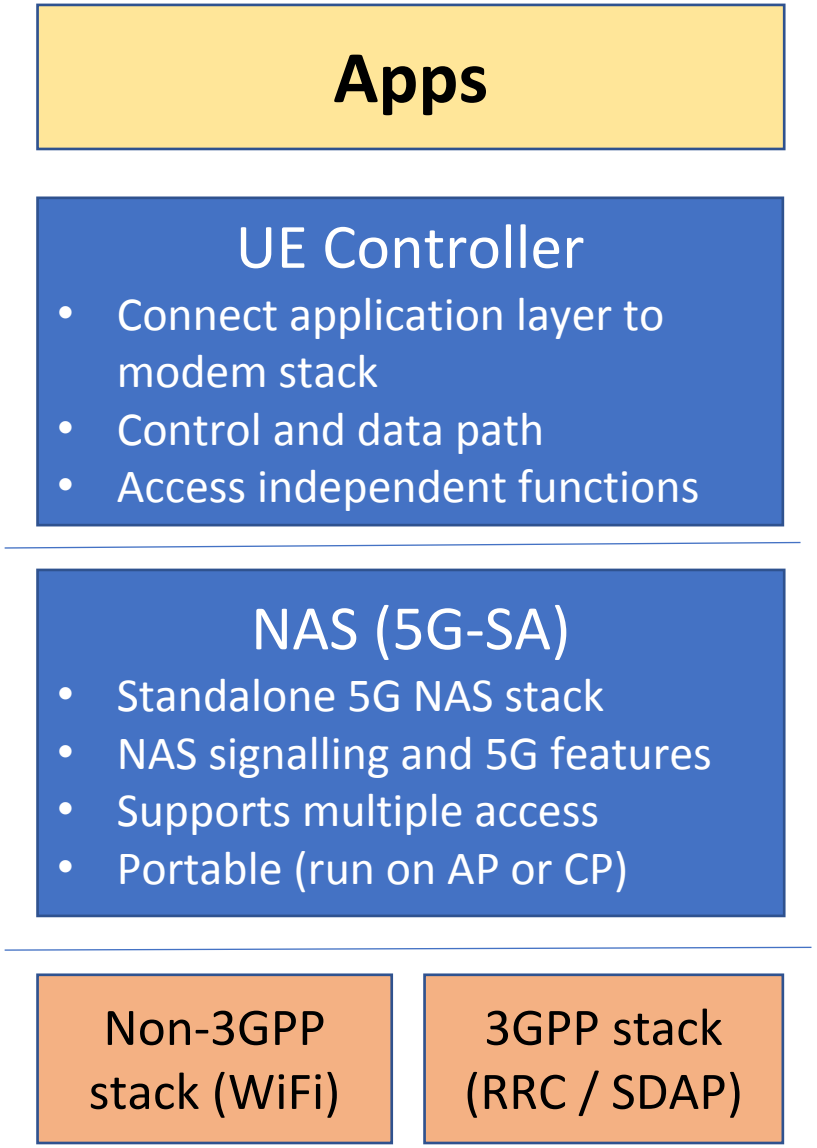
UE NAS and Higher Layers provide the Access independent functionalities of the UE

Overview of the Higher Layers of UE Stack



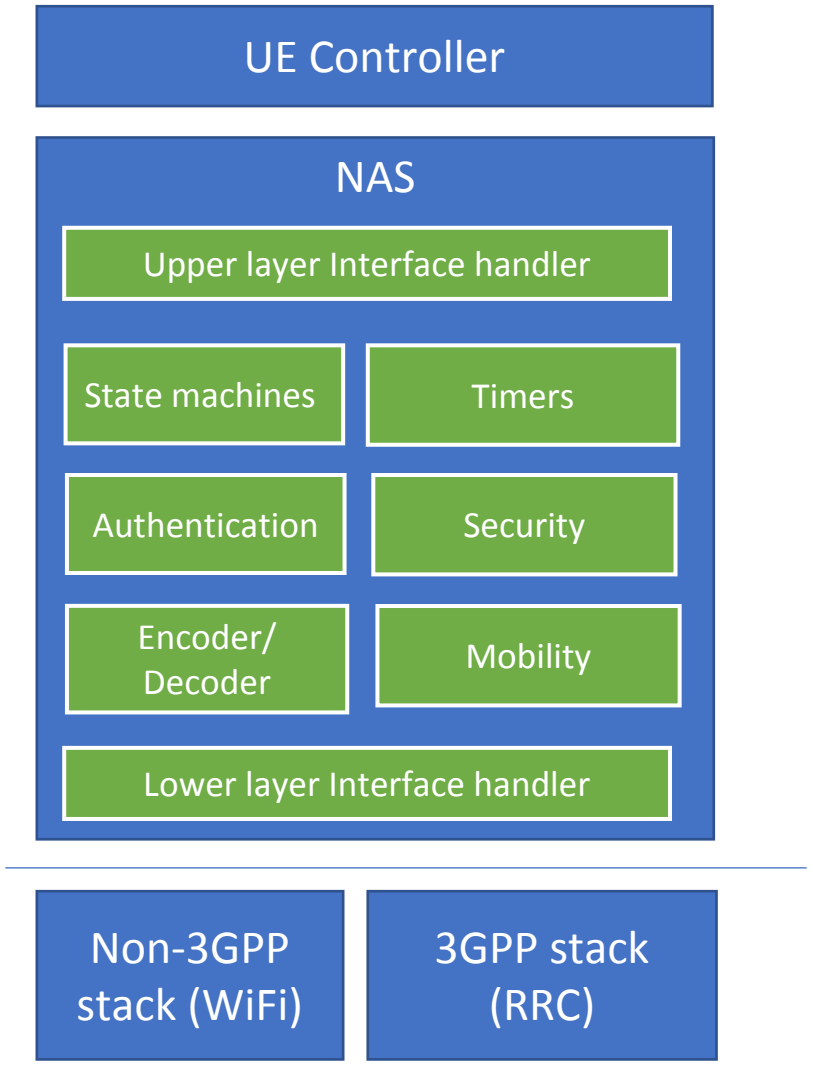
- Test bed UE is a full stack solution
- Higher Layers of UE is composed of
  - 3GPP Standards defined NAS layer
  - Application interface layer (UE Controller)
- All Interfaces are
  - Open with published APIs/protocols
  - Flexible, supporting multiple types of connectivity such as IP, shared memory
- NAS is designed to run
  - (1) On the modem processor (legacy)
  - (2) On the application processor (supporting NR and non-3GPP RATs)

Higher Layers of UE Stack



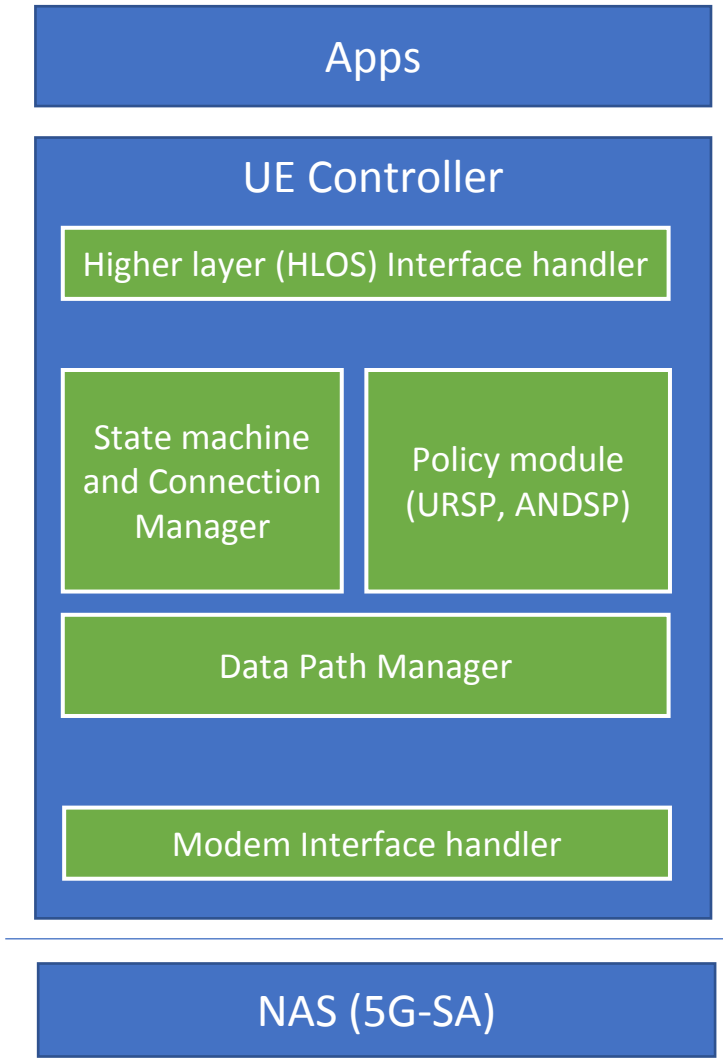
- UE Controller implements Application interface layers
  - Abstracts higher layer OS and applications from core modem stack
  - Sets up and manages both Control and Data
  - Implements policy control for access decisions
- NAS implements the NAS procedures and State machines as defined by 3GPP

UE NAS



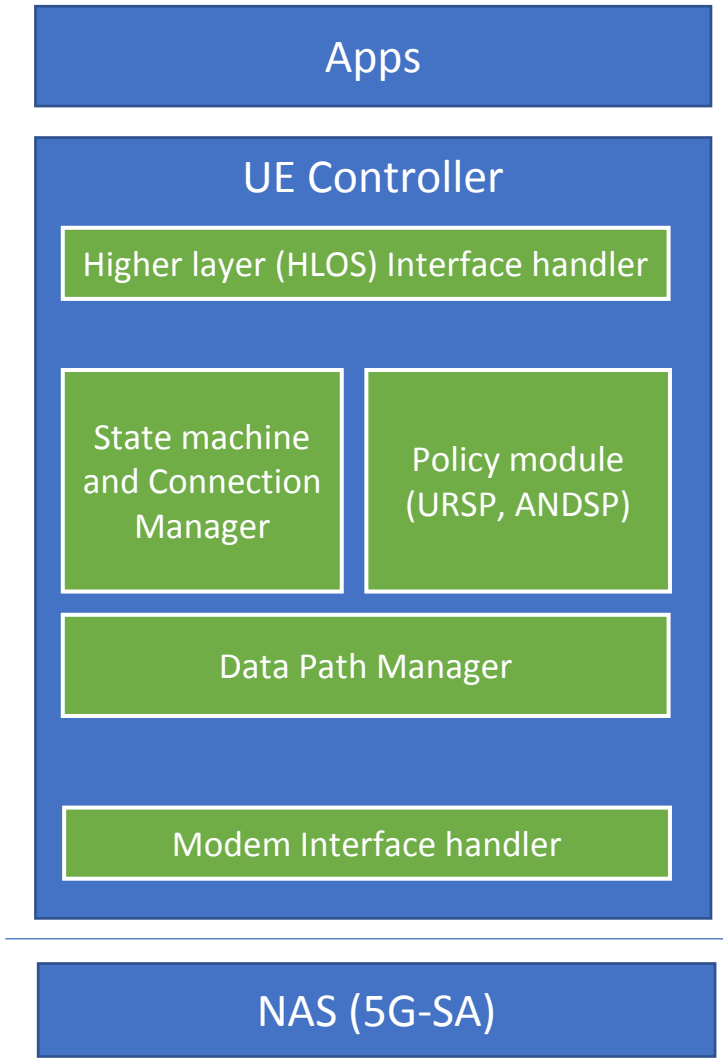
- Release 15 compliant - Standalone (SA) mode
- Supports multiple access - Non3GPP (WiFi) and 3GPP (NR)
- Implements NAS procedures such as Registration, PDU sessions, Mobility
- Supports features such as QoS, Slicing
- Standard State machines, Timers etc.
- Standard algorithms for Authentication and Security
- Interface handlers for modular connectivity
- Developed as a portable layer, can be integrated into any modem stack

UE Application Interface layers



- Connects Applications to the Modem stacks
- Supports multiple Access – 3GPP 5G modem and Non3GPP WiFi stack
- Supports Control plane type functionality to connect external user devices
- Implements Interfaces to adjacent layers
  - Abstracting Higher Layer OS (Linux, Android, Windows) on the upper edge
  - Modem specific handler to talk to NAS and SDAP on the lower edge

UE Application Interface layers (contd.)



- Provides IP connectivity
  - Manages (set up, teardown and control of) data interfaces to
  - Expose the access network assigned IP address(s) to applications on the AP
- Provides Data path management
  - Manages the Data packet flow to/from the modem (including buffering and flow control as needed)
- Supports multiple PDU sessions
- Supports QoS flows
- Implements policy control
  - Decision making on which access and data session to connect applications over

Thank You

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Click for CEWiT Main Menu 

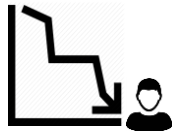
Click for Project Main Menu 

Orchestrator for 5G Testbed

Wipro, Prodapt, Chakra, CEWiT

Need for Orchestration

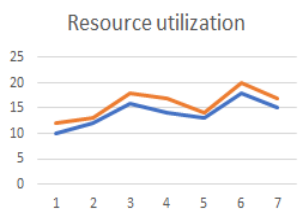
Generic



Decrease human intervention (cost, time, quality)

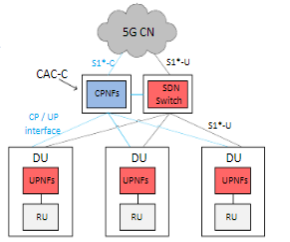
Quicker actions, quicker response to changes & issues

Increased SLA/KPI adherence (direct & indirect benefits)

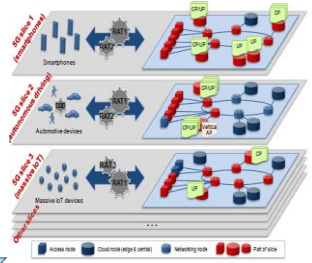


Use optimal resources, dynamic network *shaping* (CAPEX, OPEX saving)

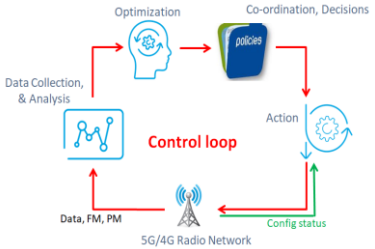
5G-specific



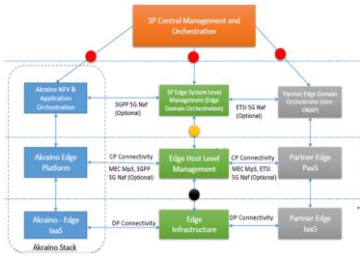
Software-Defined RAN, service-based & cloud-native core



Use case diversity (including Industry Vertical use cases) & Network Slicing



Increase in network heterogeneity, density & complexity → closed loop control essential



"Network edge" plays an important role, requiring "Edge Orchestration"

Introduction to ONAP

ONAP is one of the leading open source end-to-end orchestrators that is being evolved to meet 5G requirements

OPEN NETWORK AUTOMATION PLATFORM

Leading Open source option for network function virtualisation management, orchestration (MANO) and automation

Platform above the infrastructure layer that automates the network

Allows the end users to connect products and services through the infrastructure and allows deployment of VNFs and scaling of the network in a fully automated manner

Architecture contains different software Subsystems that are part of design time and execution time environment to execute the designed platform

ONAP - Tuned to 5G's Dynamics

Why ONAP??

5G Dynamism

- **Multiple Services Concurrently**
  - 50x more speed
  - 10x low latency
  - 1000x more capacity
- **Network Slicing for Vertical Industries**
  - Autonomous vehicles - Low latency, high mobility
  - IoT – low cost, low bandwidth
  - Factories – High Reliability, low mobility
  - Video – High bandwidth, high latency
- **Advanced Beamforming**
- **5G RAN Split Architecture**
- **Service based Architecture in 5G Core**

ONAP Capabilities

- **ONAP automates 5G using SDN and NFV technologies**
- **End-to-End Life Cycle Management of 5G Network services**
- **Hybrid 5G Radio Network and Core Network**
  - 5G's some part of RAN to be deployed as Physical Network Elements (PNFs)
  - Deployment of Core Network Functions as VNFs
- **Edge Cloud**
  - Instantiation of network and media functions closer to consumer/user
- **Real time analytics and Network Automation**
  - To influence orchestration functions like scaling, fault management and performance optimization

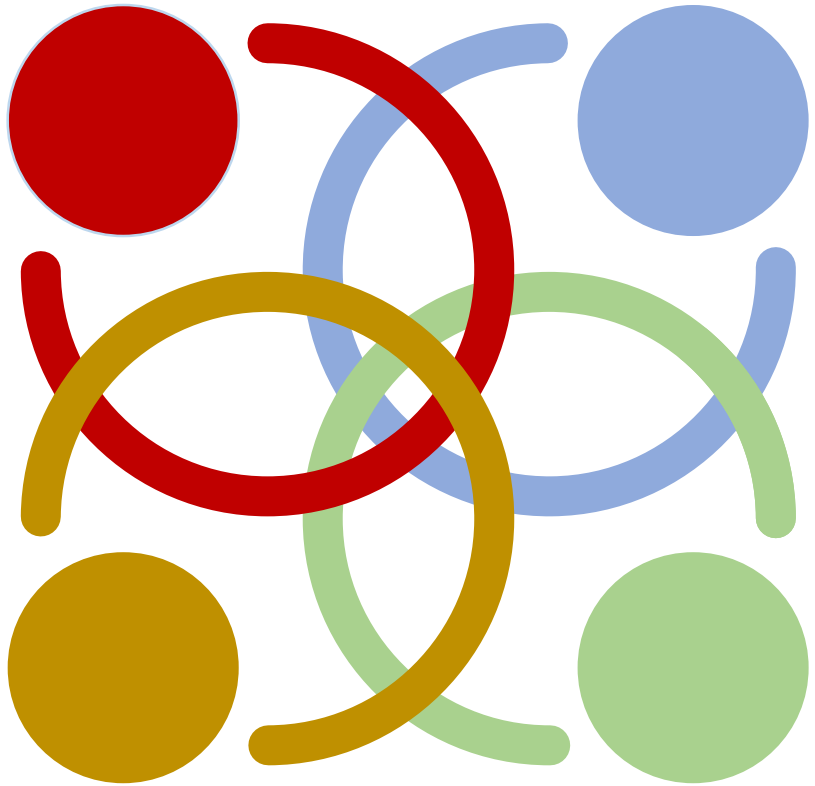
ONAP - Its Benefits

5G Network Optimisation

- Model Driven Design and Orchestration
- Real Time Analysis
- Network Slicing

Policy-based Control and Analytics

- Based on closed loop analysis
- AI/ML based algorithms that will fully automate the network



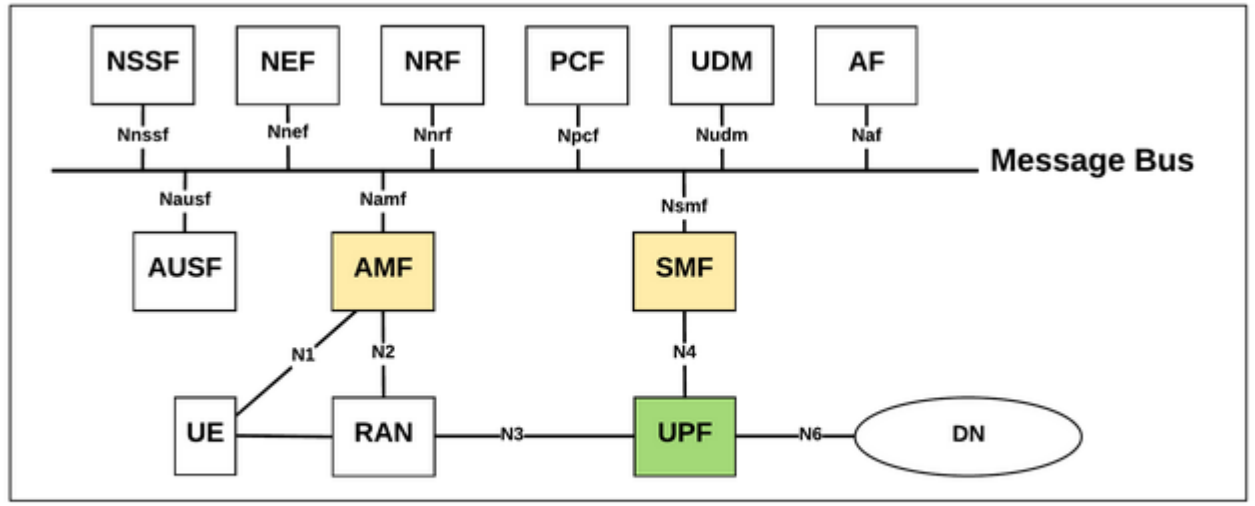
Scaling and Healing

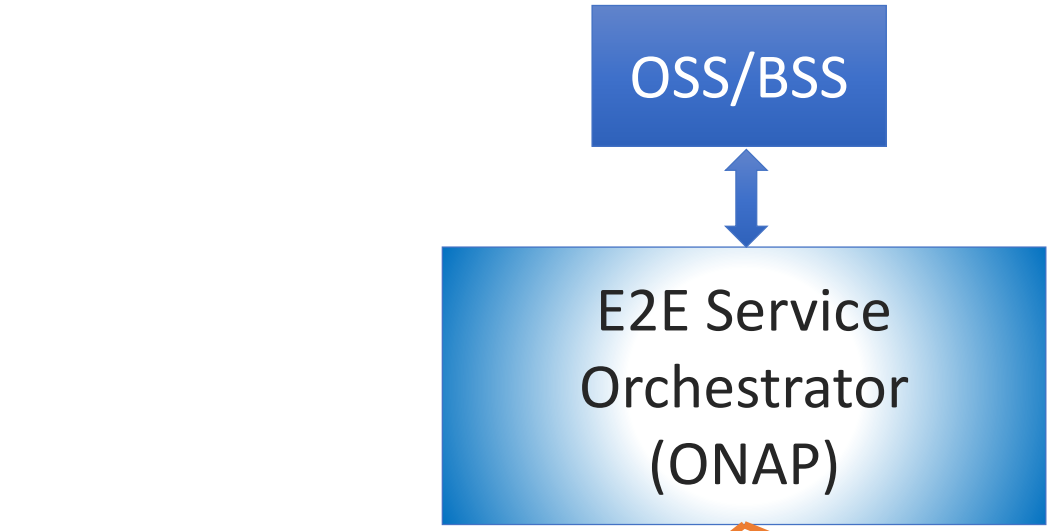
- Closed loop automation and Scale-in/ Scale out of RAN and Core NFs to provide a balanced network with the right amount of capacity.
- Software Defined Control

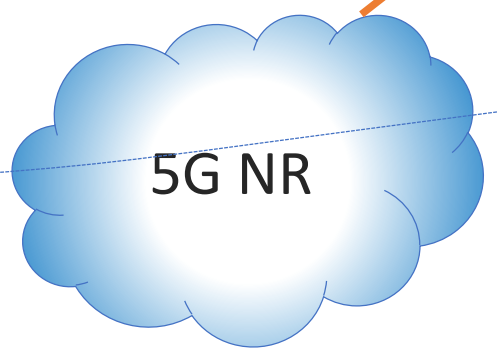
End User Experience

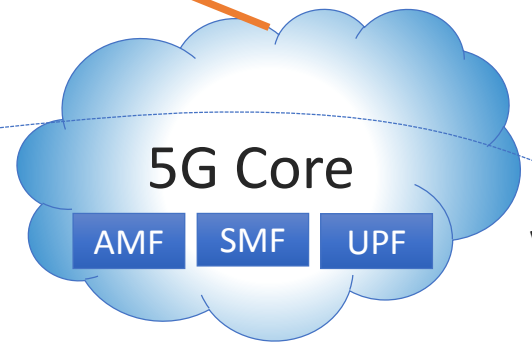
- Enhanced user experience
- E2E execution with full automation and less manual intervention

5G Use case







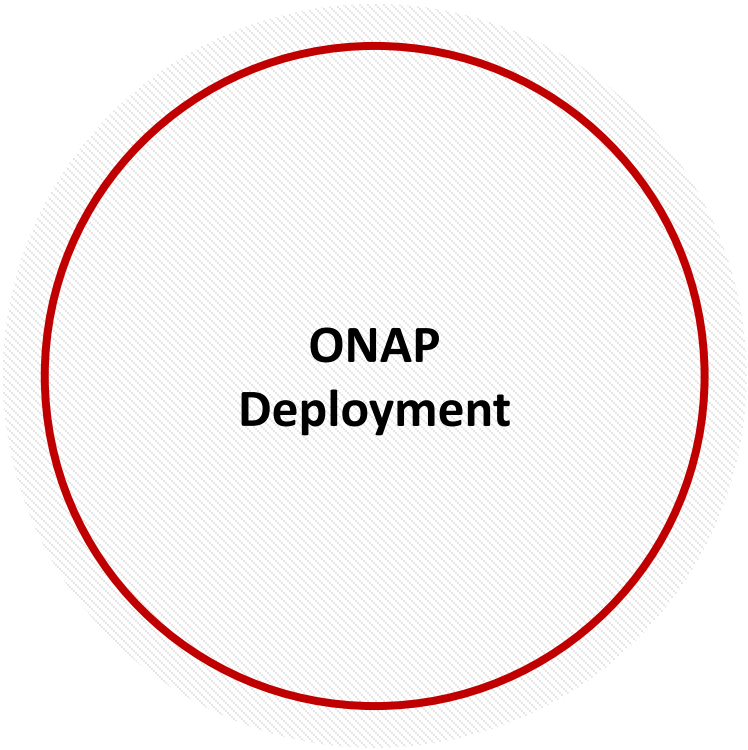


Video server

UE

Use case demonstrates Orchestrating E2E 5G RAN and Core services using ONAP

Use Case Steps



Modeling and Service Chaining

- Deployment Artifacts, Heat templates,
- Virtual Link, Connection Point

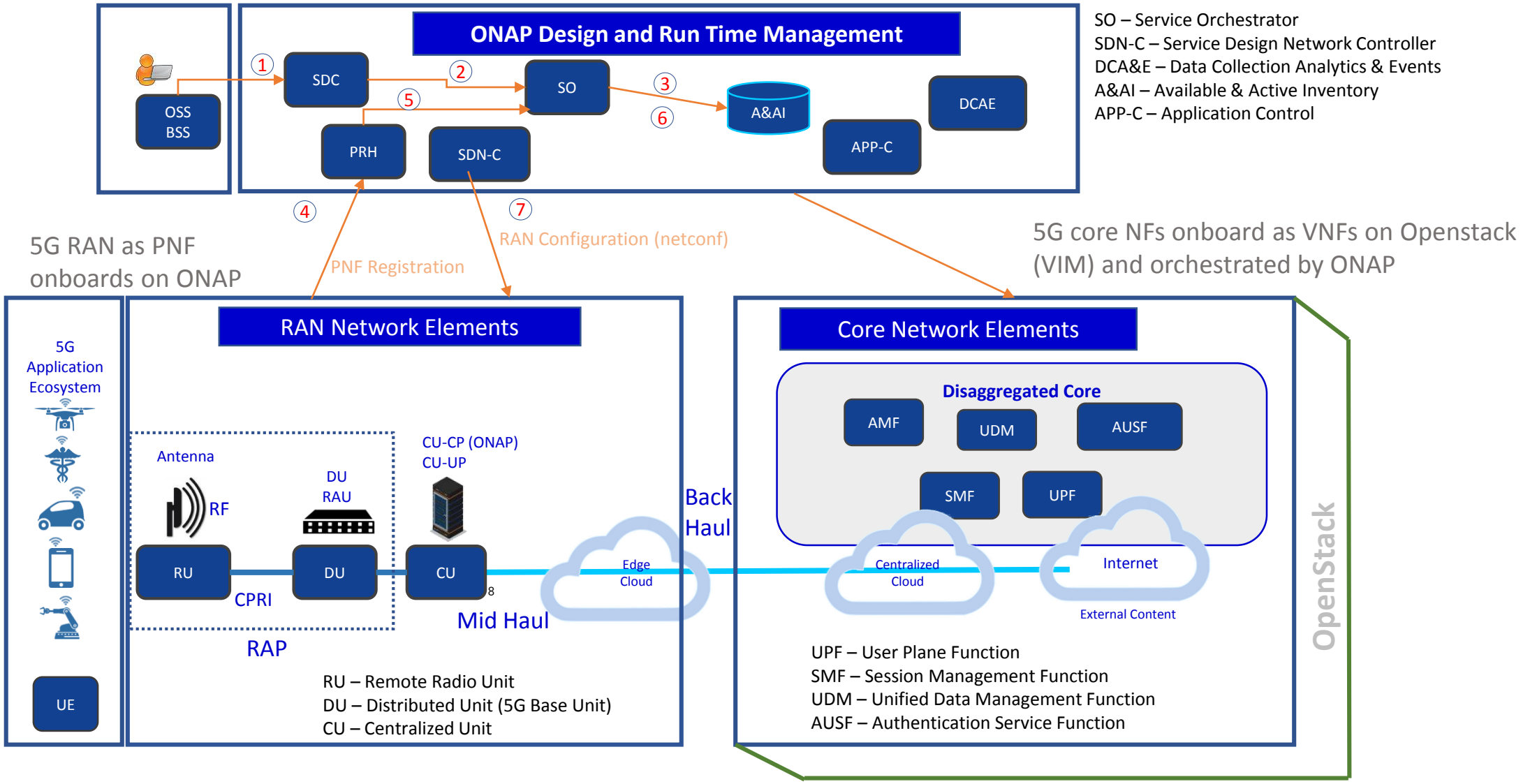
RAN/PNF

- 5G RAN as PNF onboards on ONAP
- PNF Registration – Plug and Play
- PNF configured using NETCONF

Core/VNFs

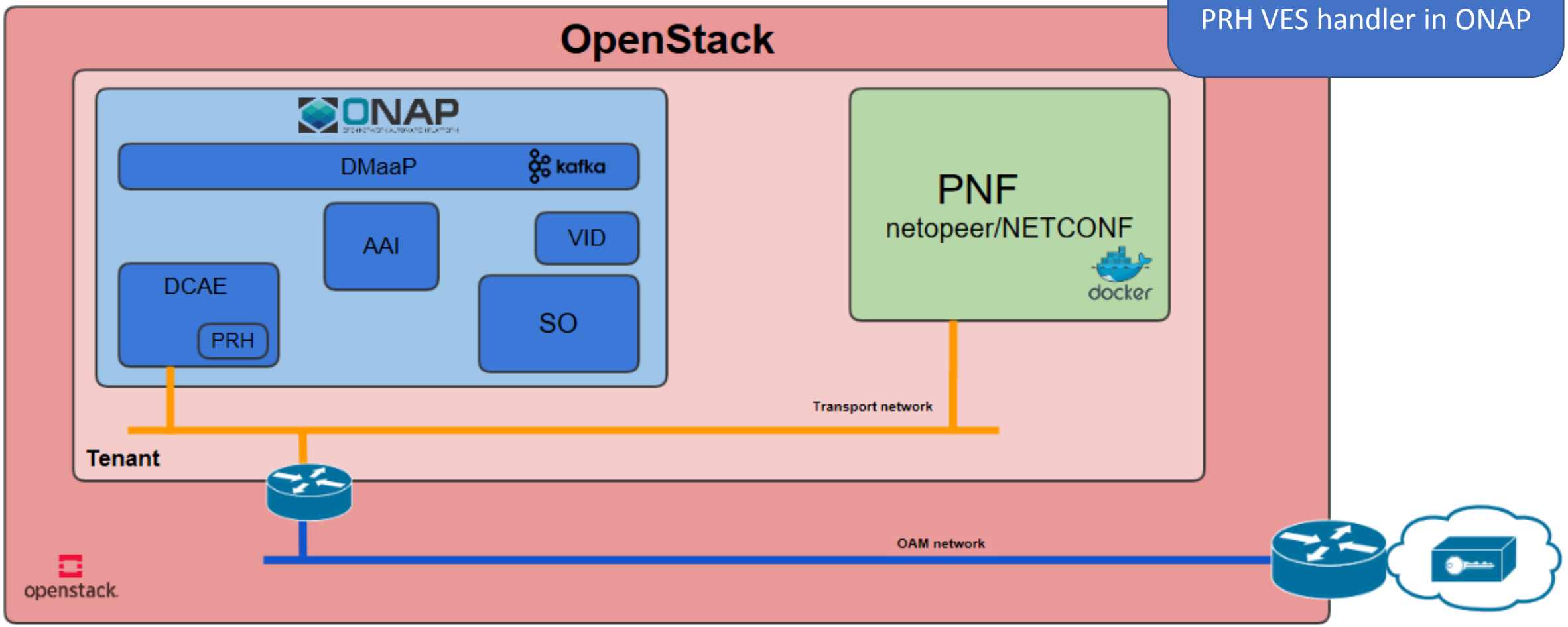
- Service Design of 5G Core Network Functions as VNFs
- VNF onboarding and Service Instantiation
- UE Registration and Traffic flow

Functional Architecture



PNF in the Deployment stack

PNF Integrates with ONAP by getting registered with PRH VES handler in ONAP



PNF Plug and Play

Design Time

① PNF Modeling

Resources Definition/Services Definition
SDC: PNF (physical element) Modeling
Distribution of types

Run-Time (Instances)

② PNF Instance Declaration

PNF Infrastructure Service Declaration
First part of PNF instantiation
PNF A&AI Entry created
15 16 17 18 19 20 21 22

③ PNF Boot-strapping

PNF Powers up and Boot-straps
PNF performs a "Plug and Play" procedure

Equipment vendor proprietary steps

④ PNF Contacts ONAP

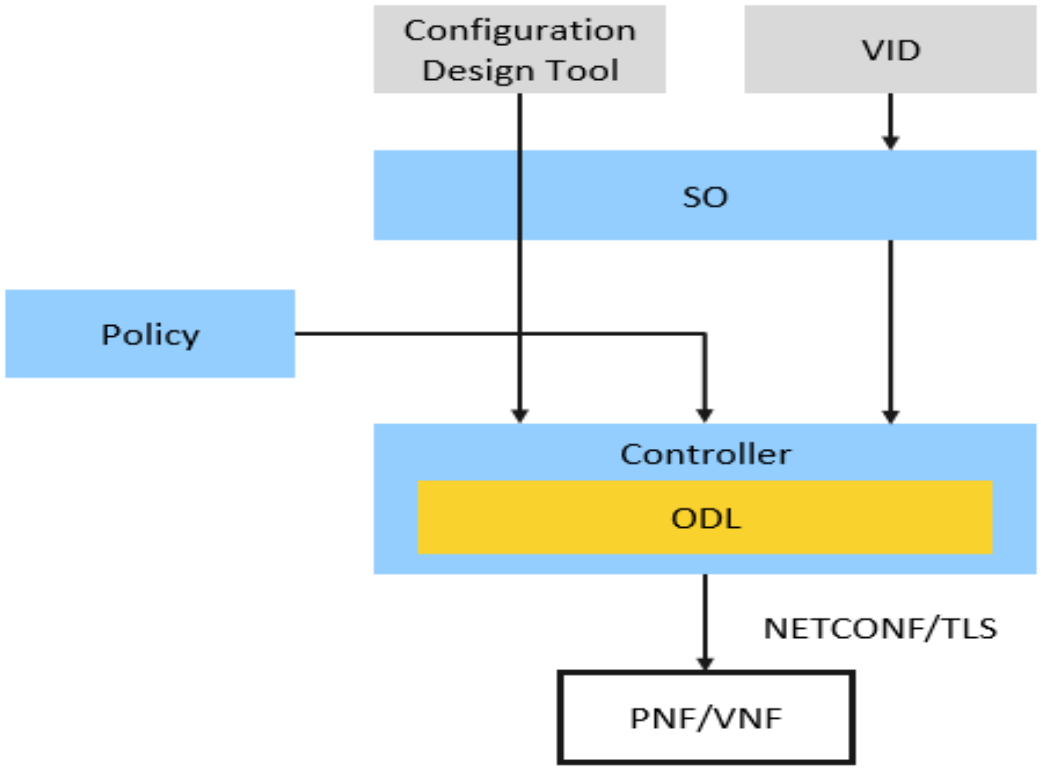
PNF connects to ONAP via a Registration Event
PNF Registration Handler (PRH) processes the event
25 26 27 28 29 30 31

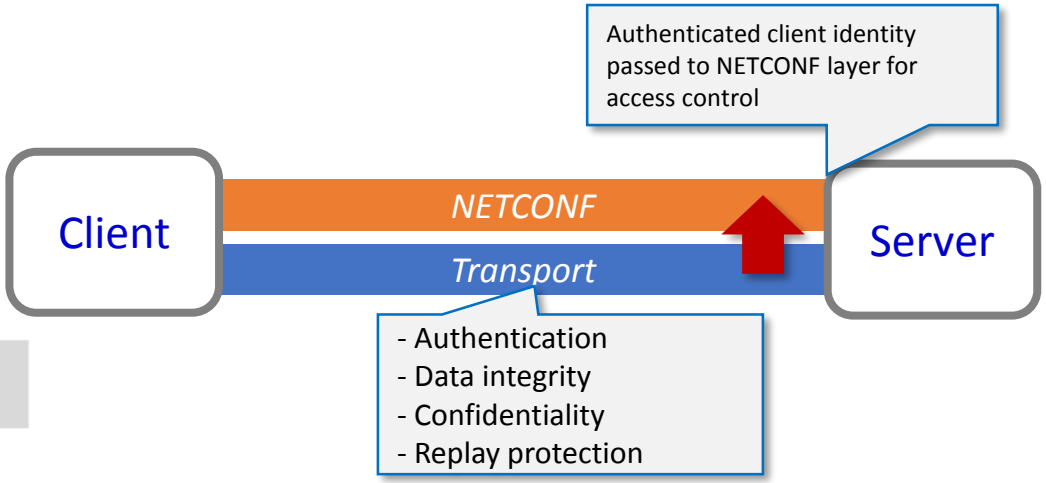
⑤ PNF Activation

Connection points configured
Second part of PNF service instantiation
PNF configured and ready to provide service
34 35 36 37 38 39 40 41 42

PNF Configuration with Netconf

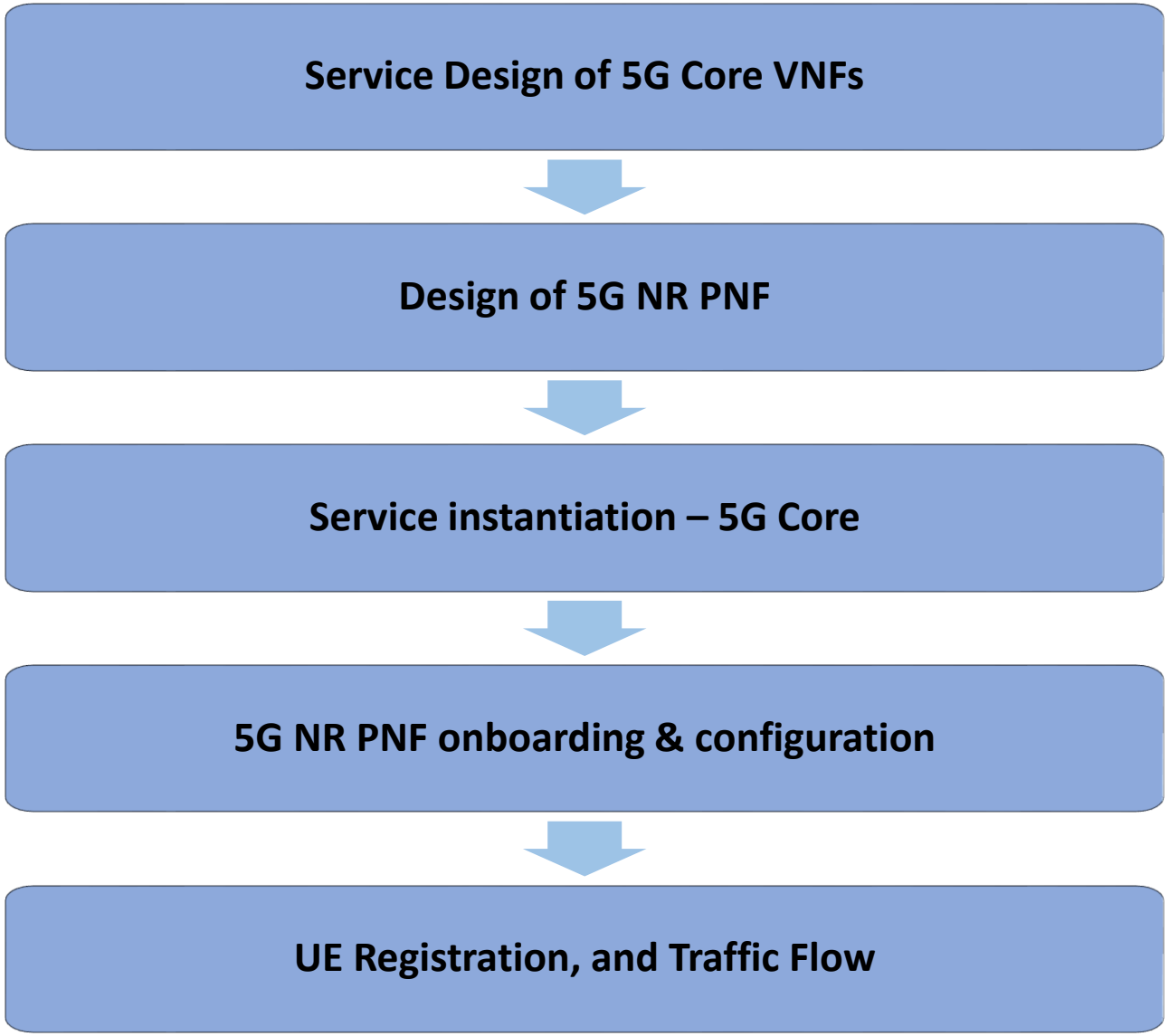
Configure PNF using NETCONF for north bound APIs





- Post-instantiation (triggered by SO)
- Includes final configuration step (36/37) in the PNF PnP
- Configuration modification (e.g., triggered by Policy)
- Support for NETCONF over TLS (RFC7589)
- Support for YANG 1.1 (RFC7950) modules in addition to YANG 1.0

Demo sequence



Future Roadmap

Closed Loop control

Performance Management

Integration with Phase 1 of 5G NR

RAN Orchestration

Network Slicing

Transport orchestration

Full integration with 5G NR and 5GC

E2E Service & Network Slice Orchestration

Heterogeneous access

AI/Analytics, SON and other use cases