tsdsi India's Telecom SDO Years of developing ICT Standards celebrating 10

NCC

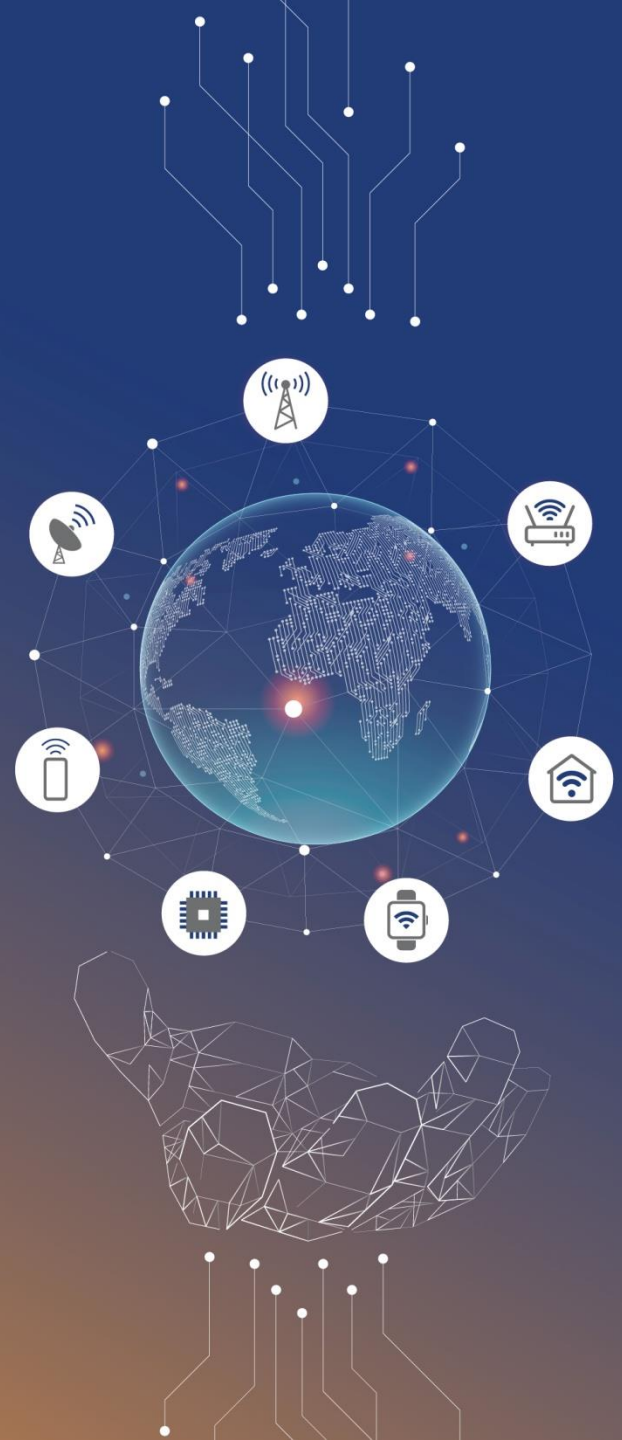
Workshop on

Standards-driven Research @ NCC 2024

28th February 2024

09:00 to 17:30 IST

IIT Madras



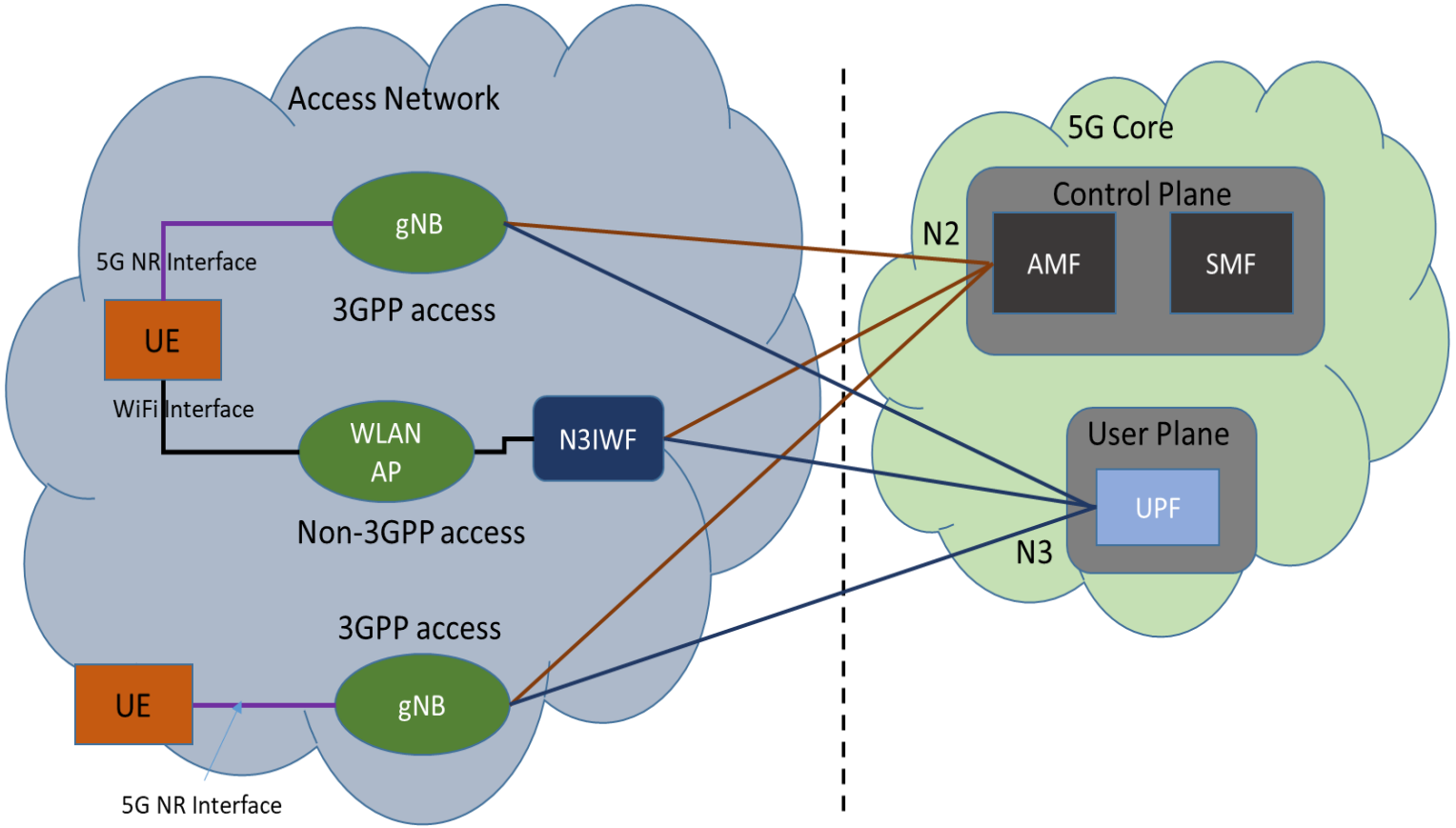
Workshop on Standards-driven Research@NCC 2024

Motivation for SDR@IITB - Evolution of Mobile Network Architecture

(Case studies of research-based contributions to standards)

Pranav Jha
Scientist, Department of Electrical Engineering
Indian Institute of Technology Bombay, Mumbai

5GS Architecture - High Level View



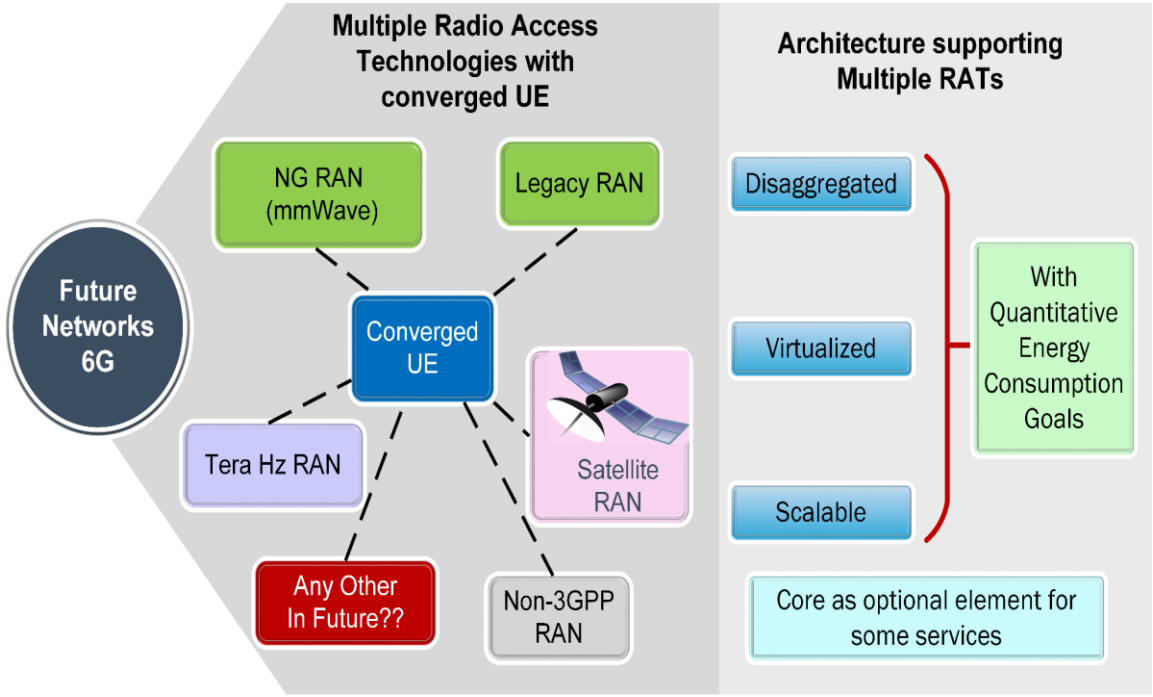
- UE exchanges signalling messages with the network before it can receive communication services

- Access and Core Network
- 3GPP 5GS allows integration of
  - Different access technologies to a converged core
  - Same Interface to Core
- 3GPP access technologies
  - LTE, 5G-NR, NTN
- Non-3GPP access technologies
  - WLAN
  - Wireline access …

Research Topics/Questions – Beyond 5G

That drive our standardization efforts

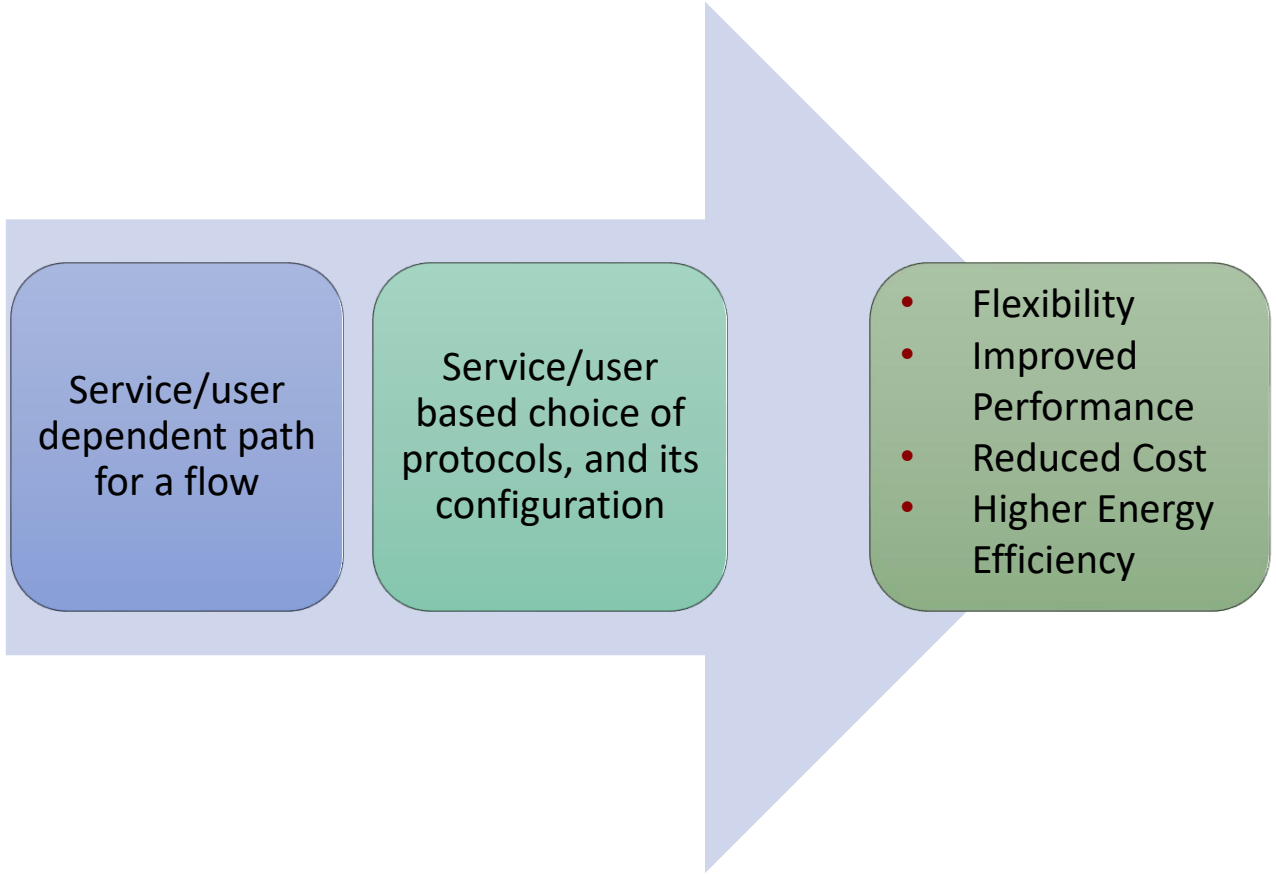
- System Architecture for 5G & beyond
  - Scalable, Flexible, Modular Architecture
  - Plug & Play Architecture
- Should we have a Unified Multi-RAT RAN?
  - Unified Treatment of Multi Connectivity
    - Most RATs perform similar functions in RAN
  - Wi-Fi Offload
  - Broadcast offload
    - Broadband Broadcast Convergence
- Softwarization of Mobile Networks
  - Separation of Control and Data Plane
  - Logically Centralized Control Plane
  - Can UE signalling be treated as another form of data (payload)? - like IP packets?
  - Use case specific protocols/flow path
- Wireless Relays – How to deploy them?



Research Topics/Questions – Mobile Networks

That drive our standardization efforts

- Can we bypass core for some users?
  - Need for core?
    - Primarily Mobility - Anchored in Core
    - Also: Authentication, Access Control…
  - A large % of mobile users may not be “mobile” any more
    - Rural Broadband Connectivity, IoT …
  - Can we bypass core for such users?
    - Direct Connectivity to Internet from RAN
- Should we decouple RAN from Core?
  - Flexible Architecture
    - Interworking of any RAN with any Core
    - Allow 5G NR RAN Connect to 4G Core - NSA
  - Potentially Simpler Core
  - Service/User specific protocol/function selection
- Rural Broadband Communication



Where are we coming from?
Evolution of Cellular Mobile Network Architecture

- Originally cellular networks designed to provide a
  - Single service - voice service to mobile users
- However, with passage of time
  - It has started providing a host of data services
    - Video, Text, Audio, WWW access, IoT, …
    - Voice also a type of data flow in these networks
  - Transfers flows of data with diverse QoS requirements
- Cellular networks evolved into data networks
  - Architecture becoming similar to Internet, the primary data network
    - Gradually incorporating features of Internet
  - Likely to continue in the 6G era
- Other technologies to impact mobile network architecture
  - Communication & Computing Convergence – SDN, Cloud/Edge computing, AI/ML,…

Internet Architecture
- Scalable network architecture
- Convergence of different access technologies
- Multi-homing
- Plug-and-play network architecture

5G/6G System Architecture and Internet

- Convergence of different access technologies
  - Is based on Internet design, which is a network of networks
  - Internet can be used over any underlying L2/L1 technology such as Ethernet, WLAN, Cellular Mobile Network, …
  - In the same way, Mobile network is trying to integrate multiple access technologies within a single converged network
- Multi-homing
  - IP networks support multi-homing, where a single device can simultaneously be connected to two different networks having two different IP addresses
  - Same capability added to the Cellular Mobile Networks via features like Dual connectivity and Multi-access connectivity via 3GPP and non-3GPP access
  - Support for features like decoupling of signalling and data, ATSSS etc. are also derived from the same concept of Multi-homing

5G/6G System Architecture and Internet

- Plug-and-play network architecture
  - Ability to add and extend networks by seamlessly connecting new networks
  - Internet is a perfect example of a plug-and-play network architecture
    - Internet can be extended indefinitely by connecting new networks and nodes via IP layer
  - Mobile networks also intend to have this plug-and-play capability
  - Examples of plug and play architecture in Mobile networks?
    - Using standard N2/N3 interfaces to connect different types of access networks to core network
    - Usage of UE capability to create wireless relays and theoretically extend RAN coverage indefinitely
- Scalable network architecture
  - Internet particularly scalable
  - A set of network nodes can dynamically be added to the network to handle increased volume of data and enhance the capacity of the network
  - Mobile network intends to achieve this capability via
    - NFV, Cloud-native architecture, Modular NFs, Separation of Control and User Plane (CUPS) etc.

Standards Contribution – Case Study I

Standards Contribution – Case Study - I

- ITU-T Y.2325
  - Recommendation aims to standardize
    - An evolved Next Generation Network (NGN) Control Plane Architecture
    - Decoupled end-user signalling handling functionality from user plane control functionality
    - By treating Signalling as a Service (data) leading to uniform handling of services
    - Scalable, and Flexible architecture for “Future Networks”
  - Approved by ITU on 14 Dec 2023 as a new standard
  - To be published soon – 2024
  - Support from TEC, DOT

ITU-T Y.2325 : UE Signalling as Payload

- 5G System
  - Separate Control and User Plane Functions
- User Plane in 5G System
  - Responsible for Data Forwarding
- Control Plane in 5G System
  - Performs two types of tasks
  - Task #1
    - Controls User Plane - “Resource Control”
  - Task #2
    - Exchanges Signalling Messages with UE
    - UE Control & State Management
    - Provide services such as Mobility, Authentication…
- Let us separate Task #1 and #2
  - Separation of User Plane Control and UE Signaling Exchange functionalities?

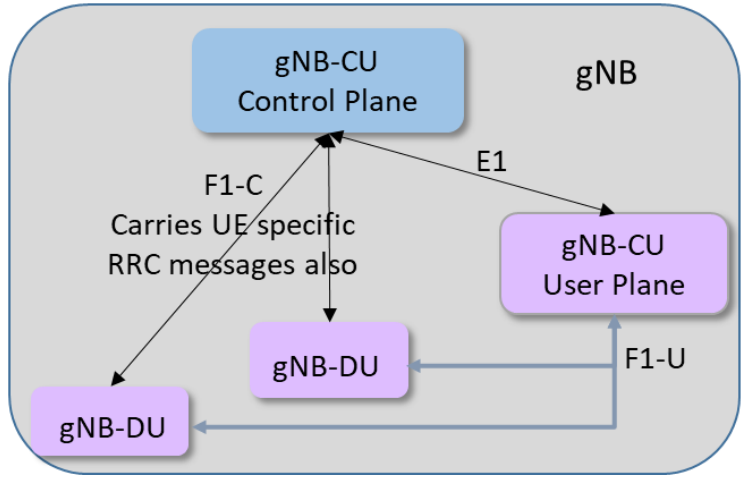
Reference: “5G-Serv: Decoupling User Control and Network Control in the 3GPP 5G Network”; Meghna Khaturia, Akshatha M Nayak, Pranav Jha, Abhay Karandikar, ICIN 2021

Draft new Recommendation ITU-T Y.Arch_NGNe_ncp: “Architectural evolution for NGN control plane by applying SDN technology”

ITU-T Y.2325 : UE Signalling as Payload

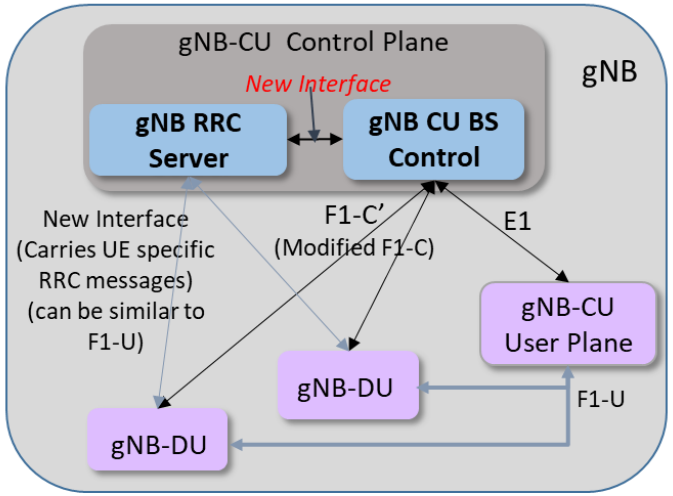
Existing gNB Architecture

(Tightly coupled RRC signalling handling + gNB Resource Control within gNB-CU-CP)



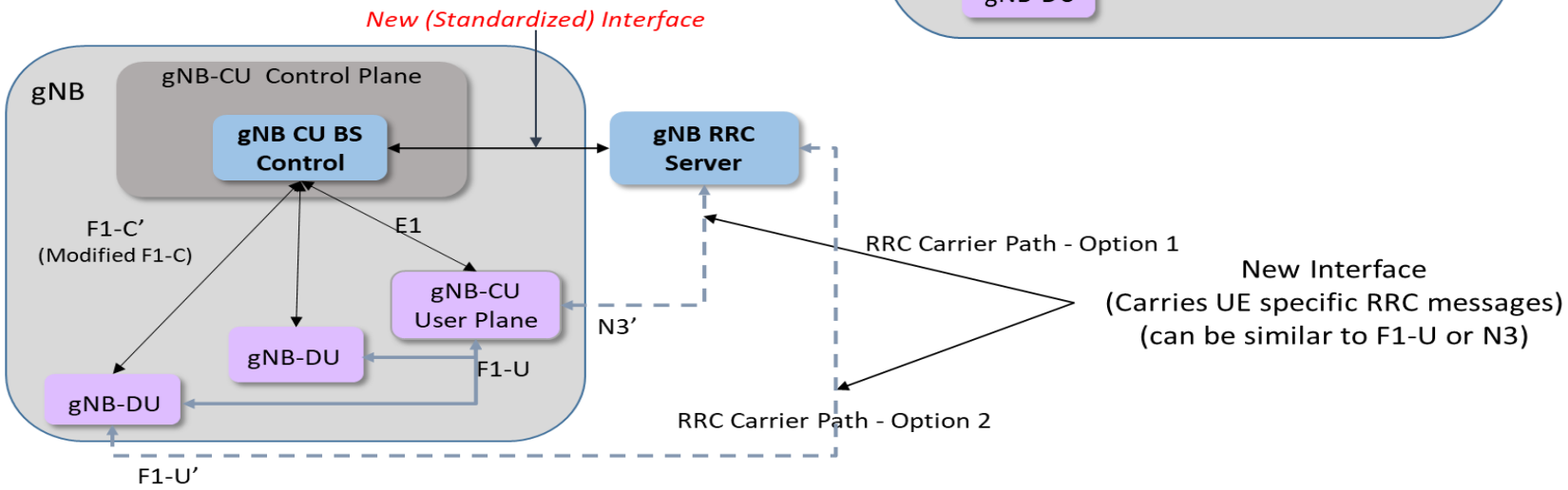
Proposed Disaggregated gNB Control – Option I

(Decoupled gNB RRC signalling handling from gNB Resource Control within gNB-CU-CP)



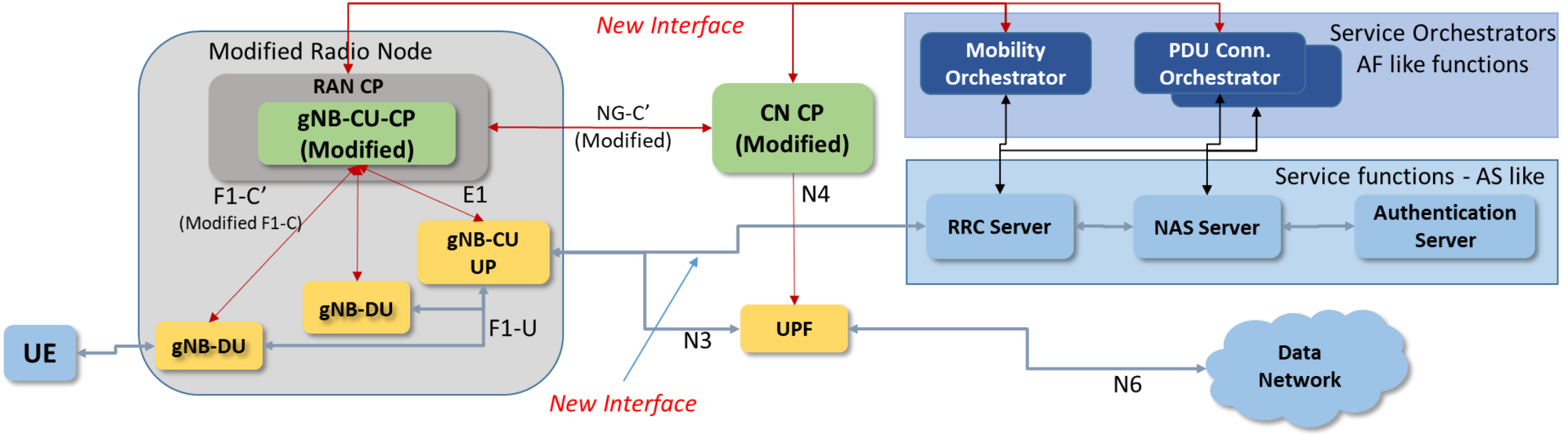
Proposed Disaggregated gNB Control – Option II

(gNB RRC Server taken out of gNB-CU-CP and placed in the user (data) plane as a service function)

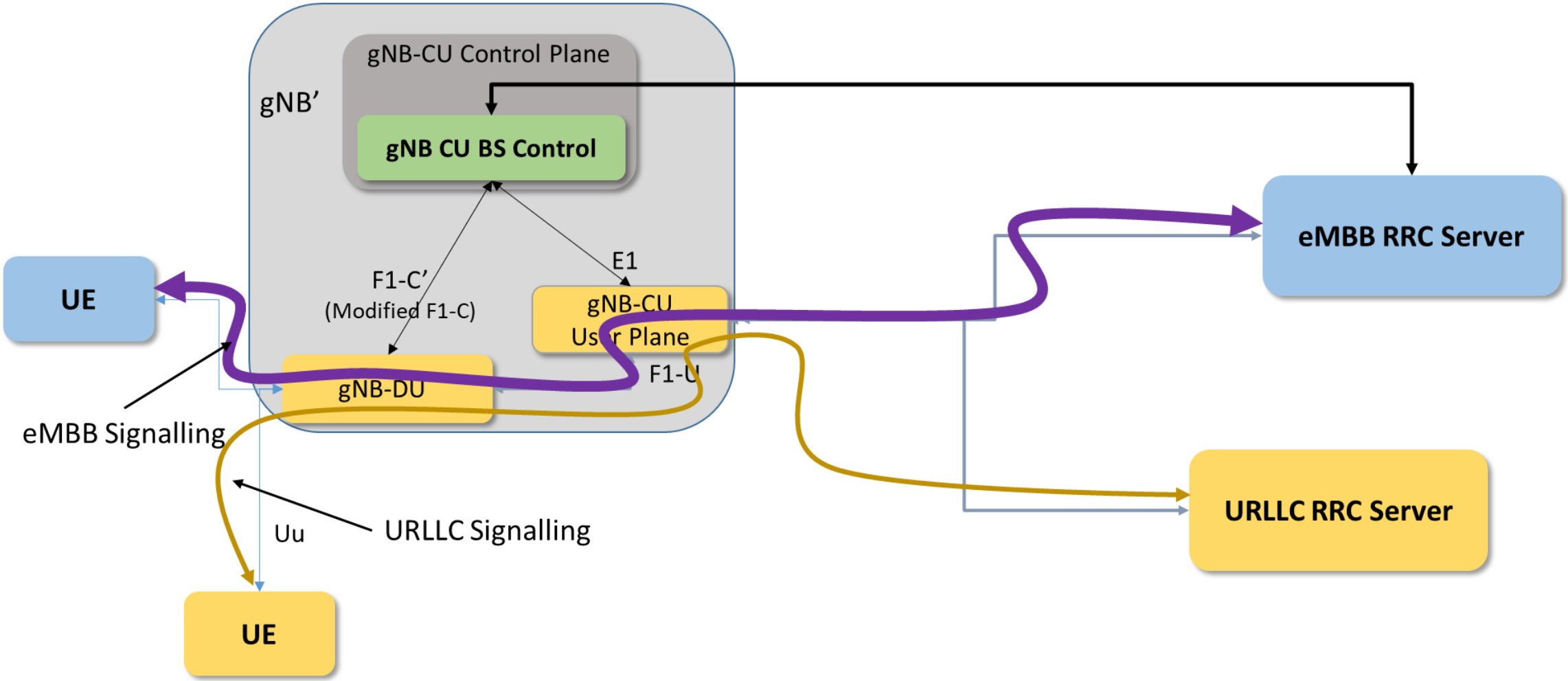


ITU-T Y.2325 : UE Signalling as Payload

- UE Signalling Exchange functionality separated from Control Plane Functions
  - Signalling Service Functions – NAS Server, RRC Server, Authentication Server, …
  - Service Function/Orchestrator – Mobility/PDU Conn. Service Orchestrator, …
- Control Plane : User Plane Control (Resource Control)
- UE Signalling (RRC/NAS) Messages
  - A form of Data (Payload) flowing through 5G network



ITU-T Y.2325 : UE Signalling as Payload



ITU-T Y.2325 : UE Signalling as Payload

Enhanced Modularity & Flexibility	• Disaggregated and Modular Control Plane • Possibility of Use case specific variants of UE Signalling Protocols • But Impact on UE Signalling Message not necessary • Flexible Signaling Handling function Placement and Chaining • Decoupling of Signalling and Data
Scalable Control Plane	• Primarily controls User Plane as in SDN paradigm • Does not exchange signalling messages with UEs • Simpler message flow & protocols (simpler NGAP, F1AP as they do not carry UE signalling messages) • Reduced Load on Control Plane - as Signaling handling a part of Data Plane
Change in Paradigm	• UE Signalling as Payload (Data) • All Services treated Uniformly - External AF/AS/IMS based and Internal services (Mobility, PDU Connectivity…) • Improved Network Access Security

Standards Contribution – Case Study – II

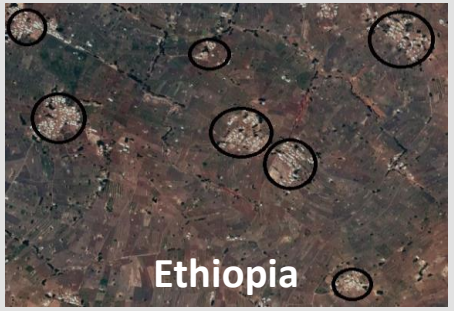
Standards Contribution – Case Study - II

- IEEE P2061 - Frugal 5G Network
  - IEEE Standard to define an Architecture for Low Mobility, Energy Efficient Network for Affordable Broadband Access
- The Standard defines
  - Wireless access network (AN)
  - (Wireless) middle-mile network (MMN) – Wireless Backhaul
  - Control architecture for AN and MMN
  - Core Bypass
- The Goal is
  - **Not** to develop new wireless access technologies
  - But to identify relevant (available) technologies and bring them together
  - To enable Affordable Broadband Access in Rural Areas
- Status
  - Standard Draft Ready
  - In IEEE SA Balloting
  - Expected IEEE SA Approval – Q2/Q3 2024

IEEE P2061 - Connecting the Unconnected – Key Challenges

Sparsely Populated Rural Settlements

Remote and difficult to reach regions



**Source: Google Earth*

Circles denote habited areas, Rest of the areas have no population

High Deployment Cost

Spectrum cost

Cost of backhaul

Scarcity of Resources

Uninterrupted power supply from the grid not available

Lack of Relevance

Most Internet content in English and a few other languages

Relevance of content limited

Relatively Lower Income

Unaffordable devices

Low average revenue per user

Challenges of Manageability

Unavailability of trained manpower

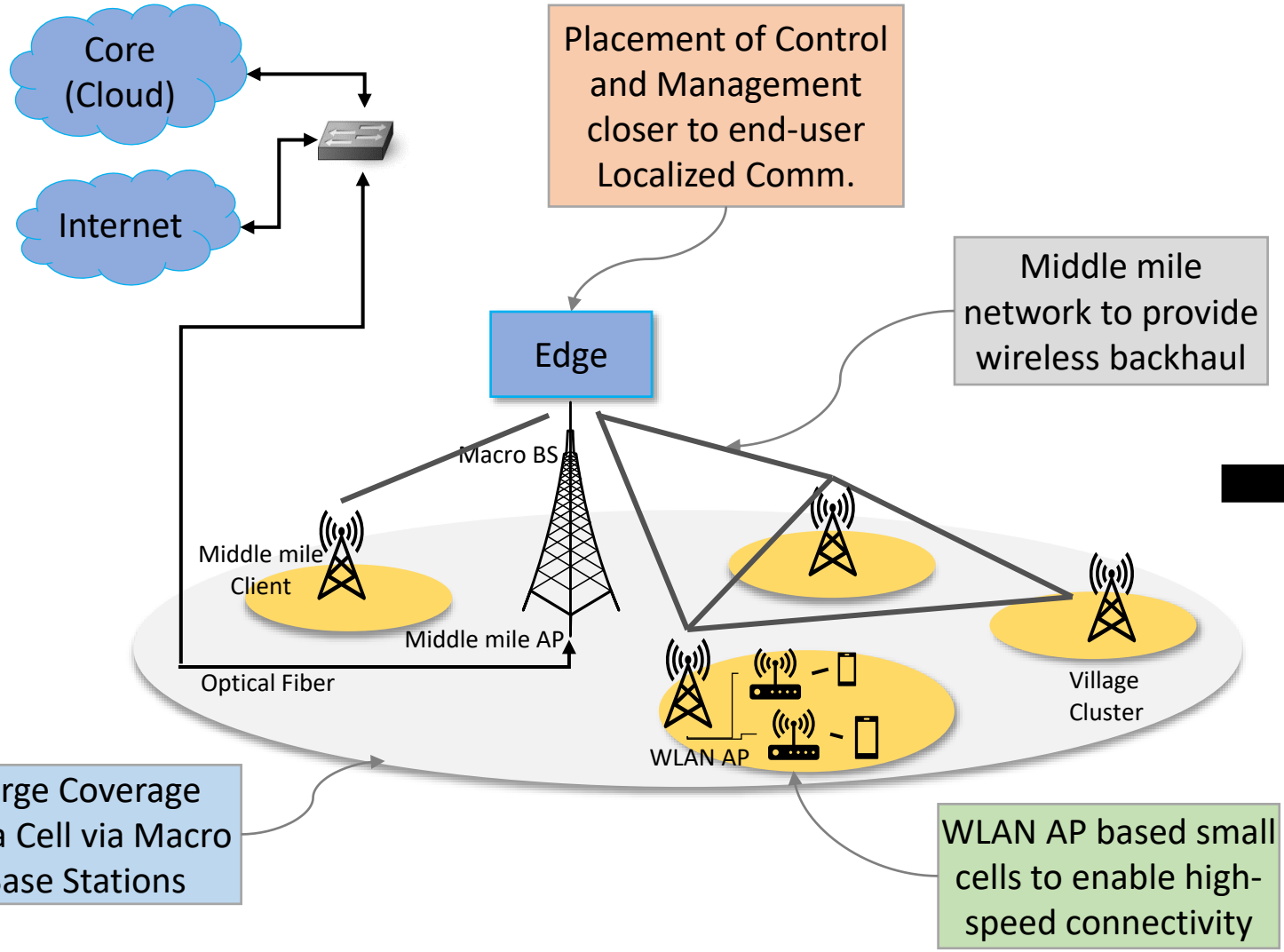
Access Constraints

Right of way issues

IEEE P2061 - Rethinking 5G Requirements for Rural Areas

- Affordability
- Limited need for mobility
- Large coverage area support
- Connectivity to sparsely populated areas
- Energy efficient solution
- Localized communication and local content generation/storage
- Easier to manage technology

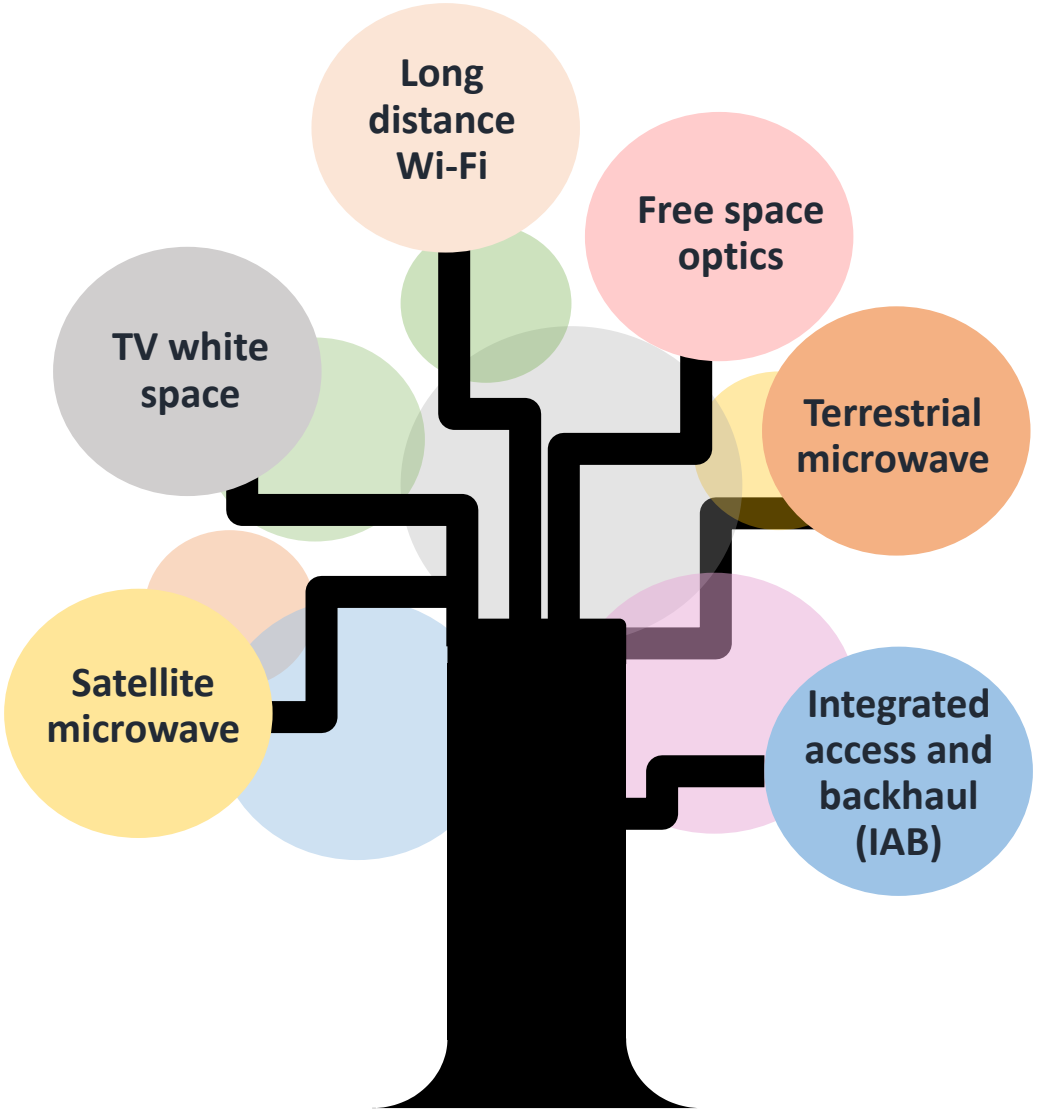
IEEE P2061 – High Level Architecture



Frugal 5G Networks (IEEE P2061)

Refers to the vision of providing broadband access to rural areas by addressing rural area requirements and challenges

IEEE P2061 - Middle Mile Technologies



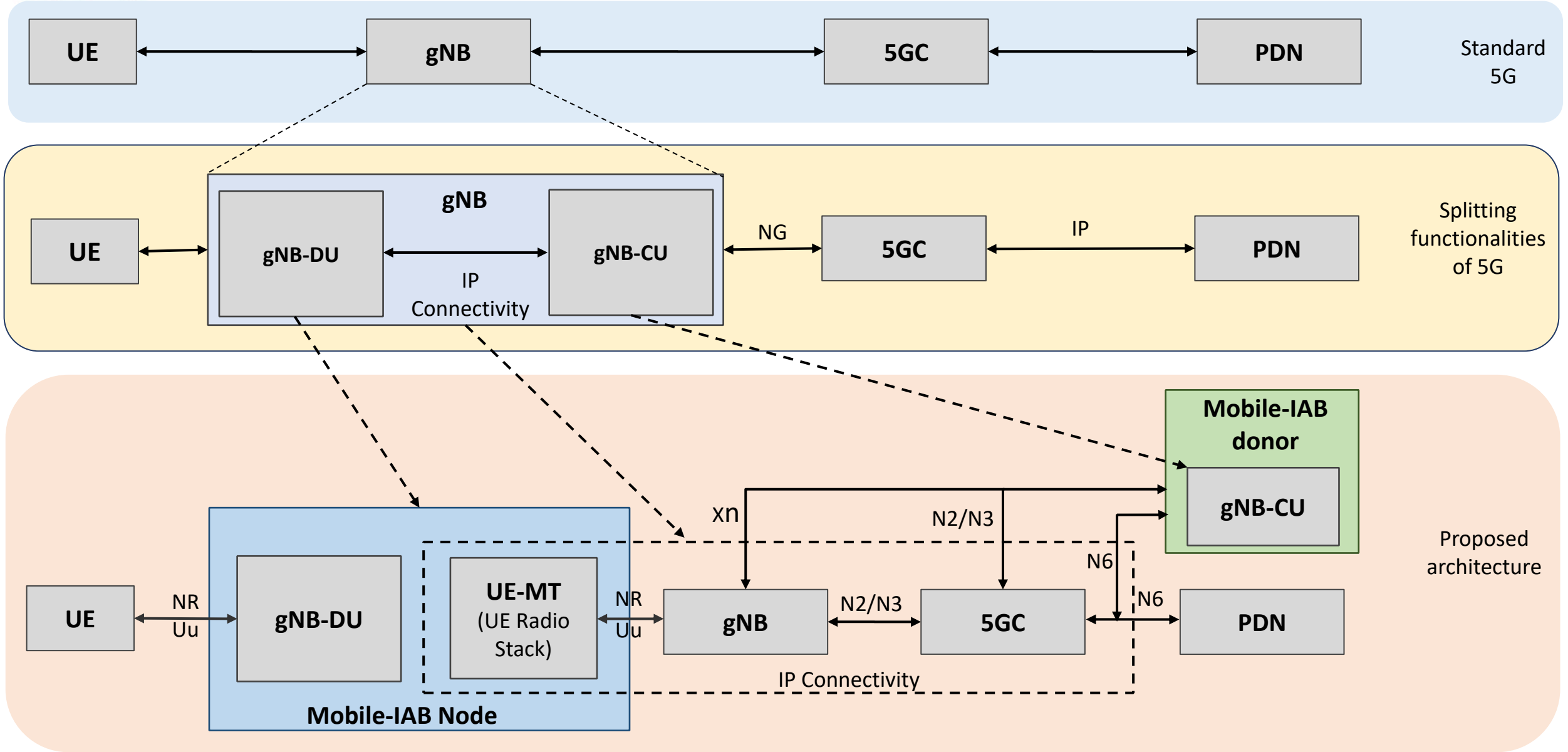
Long distance Wi-Fi (IEEE 802.11n/ac/ax)	Unlicensed spectrum 2.4-5.8 GHz (+ 6 GHz band)	Cost effective and easily deployable
TV white space (IEEE 802.22, 802.11af)	Unused channels in VHF/UHF TV band	Cognitive & database based sharing
Free space optics	Spectrum available in THz (785-1550 nm)	High directivity Sensitive to weather conditions
Terrestrial microwave	Spectrum: licensed between 6 GHz to 30 GHz	Multiband antenna and boosters for higher capacity
Satellite microwave	GEO: placed at high altitude MEO/LEO: nearer to earth	High throughput satellite (HTS): multi-spot-beam technology
Integrated access and backhaul (IAB)	Licensed 5G Spectrum	Integrated with 5G system

Standards Contribution – Case Study – III

Standards Contribution – Case Study – III

- TSDSI STD XXX V1.0.0 - A Generic Relay Architecture for 5G & Beyond
  - Plug & Play Wireless Relay
  - Usage of PDU Session as wireless backhaul
  - Work Complete - In final stages of approval under TSDSI
  - 3GPP has initiated a work item on the same idea in Release 19 on Vehicle Mounted Relays
- TSDSI TR 6026 V1.0.0 - 5G Extensions for Broadcast Offload
  - Broadcast Broadband Convergence
  - Supports Broadcast Offload
  - In final stages of approval under TSDSI
- Contributions to 3GPP – SA1/SA2
  - Wireless Relays (Vehicle Mounted Relay)
  - Broadcast Broadband Convergence
  - Multi-connectivity

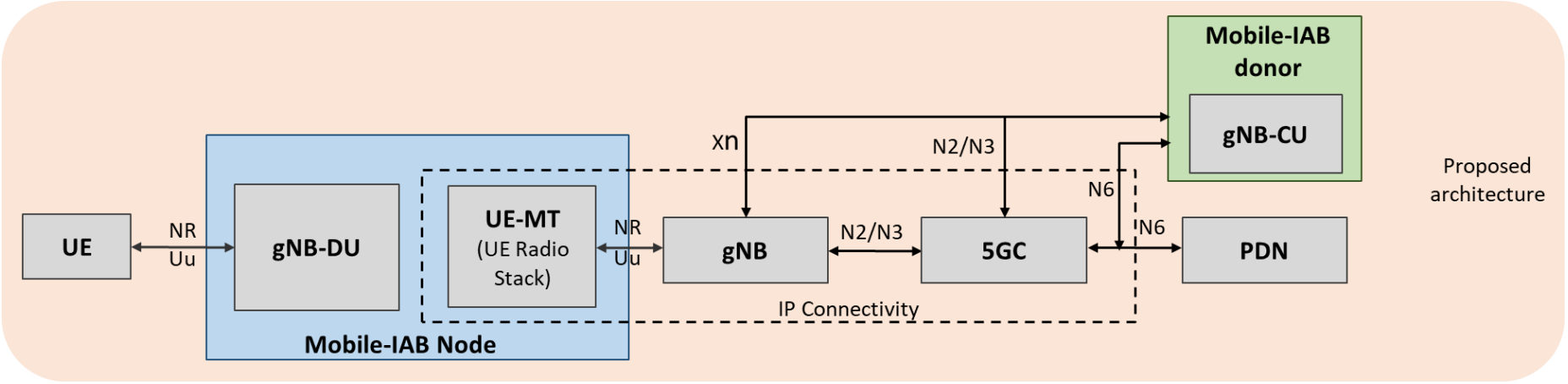
TSDSI STD XXX V1.0.0 - A Generic Plug-&-Play Relay Architecture for 5G & Beyond



TSDSI STD XXX V1.0.0 - A Generic Plug-&-Play Relay Architecture for 5G & Beyond

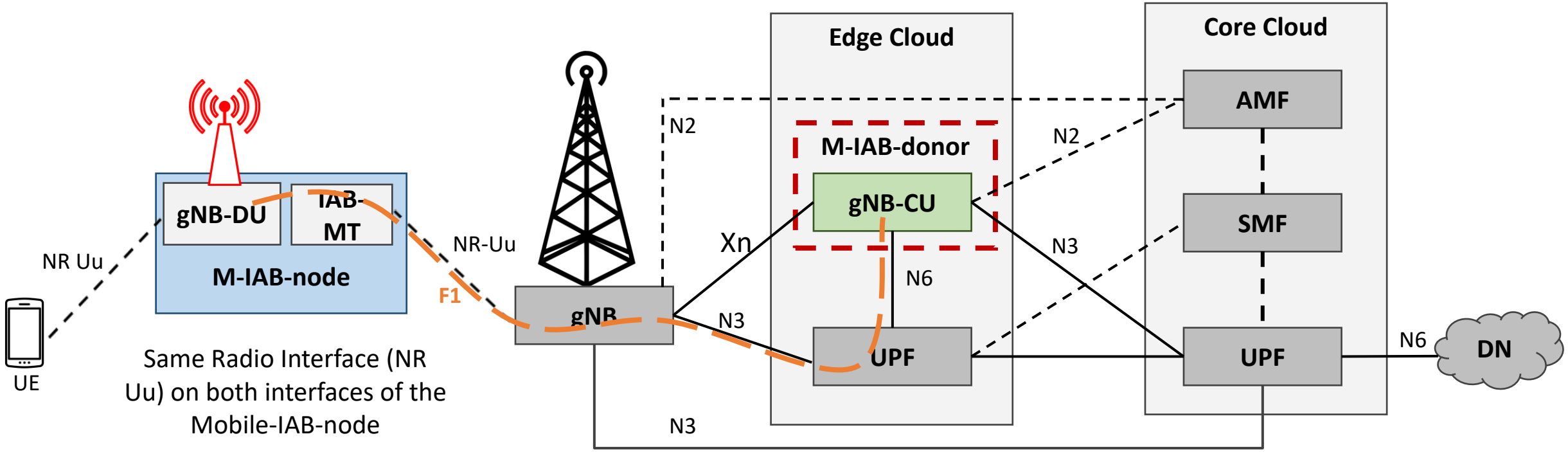
- 5G Base Station (gNB) Standard Architecture
  - gNB-DU - Radio interface towards UEs
  - gNB-CU functionality - CN interface, gNB-DU Control
  - gNB-DU and gNB-CU connected through IP based F1 interface

- IITB Mobile Relay Solution has two nodes
  - "Mobile-IAB Node"
    - Contains gNB-DU functionality along with additional UE functionality
  - "Mobile-IAB Donor"
    - It is a gNB-CU with limited modifications
- Key idea behind the solution
  - IP connectivity between M-IAB Node and M-IAB Donor enabled via PDU Session supported by the UE of M-IAB Node and the 5G Network



TSDSI STD XXX V1.0.0 - A Generic Plug-&-Play Relay Architecture for 5G & Beyond

Example of A Plug-and-Play Architecture - IITB Mobile Relay Solution



Standards Contribution – Case Study – IV

Standards Contribution – Case Study - IV

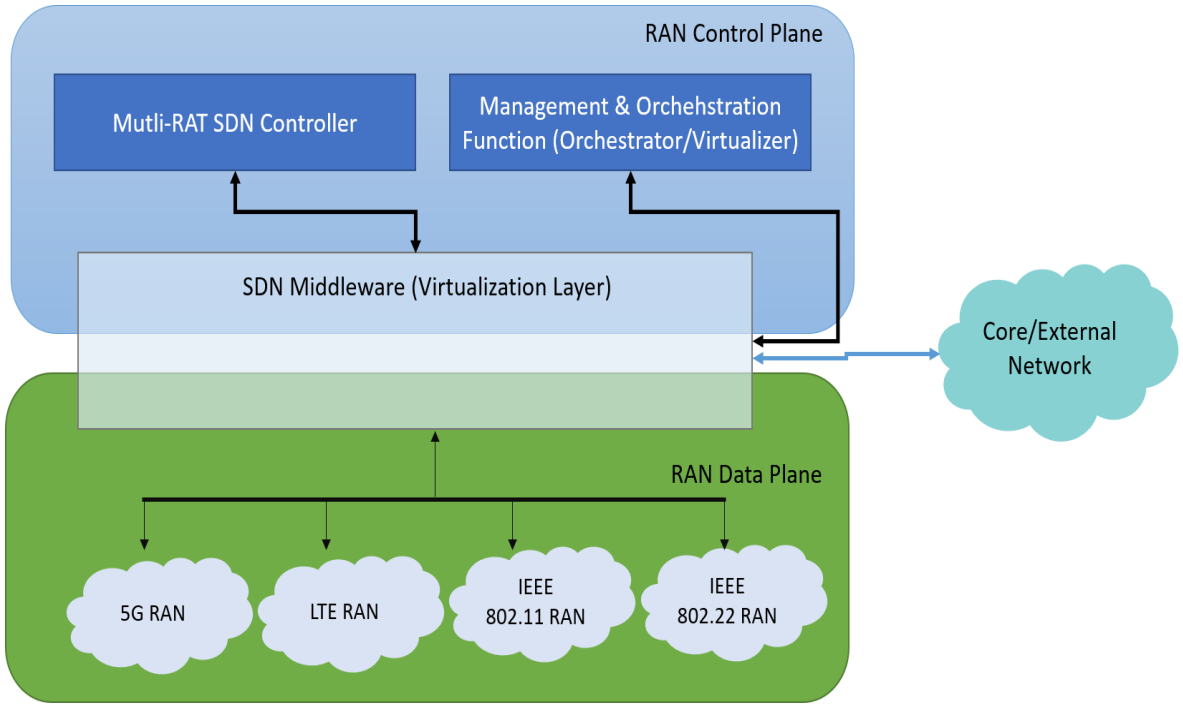
- IEEE 1930.1
  - IEEE Standard (Recommended Practice) for “beyond 5G networks”
  - Defines an
    - SDN based architecture for Multi-RAT wireless access network
    - SDN middleware to facilitate unified control of multi-RAT wireless access network
  - Approved as a new standard by IEEE SA on 16 June 2022
  - Published on 2nd September 2022
- Key Idea
  - RAN User Plane of most RATS perform similar functions
    - Radio Tx/Rx
    - PHY & MAC
    - Link Adaptation
    - Security (Encryption, Integrity)
    - Optimization (Header Compression etc.)
    - Interworking with Core
  - Can we Disaggregate/Unify RAN these simpler functions?

Reference: IEEE 1930.1-2022
“IEEE Recommended Practice for Software-Defined Networking (SDN) Based Middleware for Control and Management of Wireless Networks”

https://standards.ieee.org/ieee/1930.1/10917/

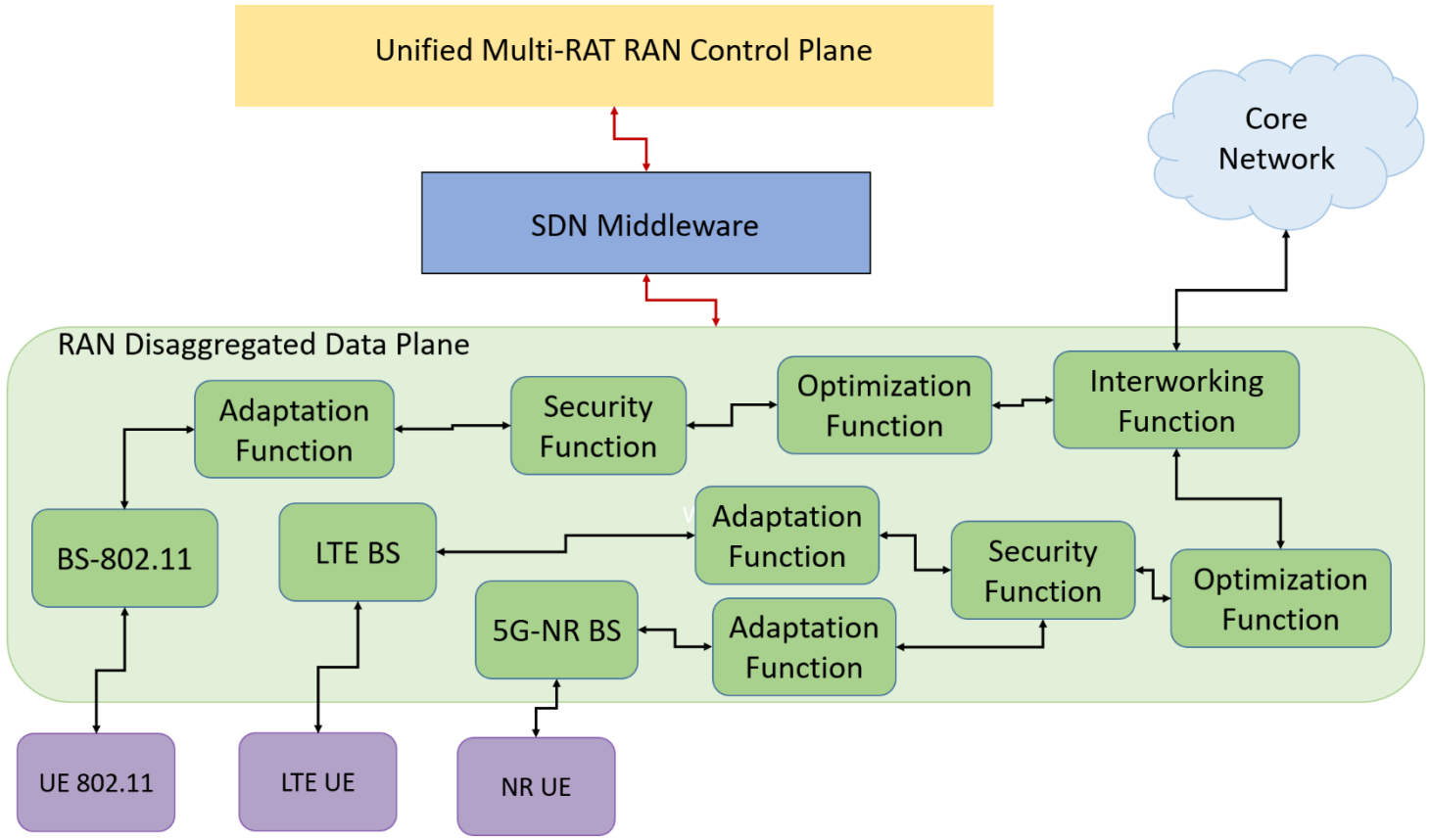
IEEE 1930.1 – Unified Multi-RAT RAN

SDN Middleware	• Abstract Information Model of underlying RAN through Virtual Entities
Multi-RAT SDN Controller	• Control & Management of the Access Network
Management and Orchestration Function	• To Orchestrate & Manage Middleware over RAN Infrastructure
Radio Access Network Infrastructure	• Disaggregated data plane - Access Points, Base Stations, Interworking Functions, …



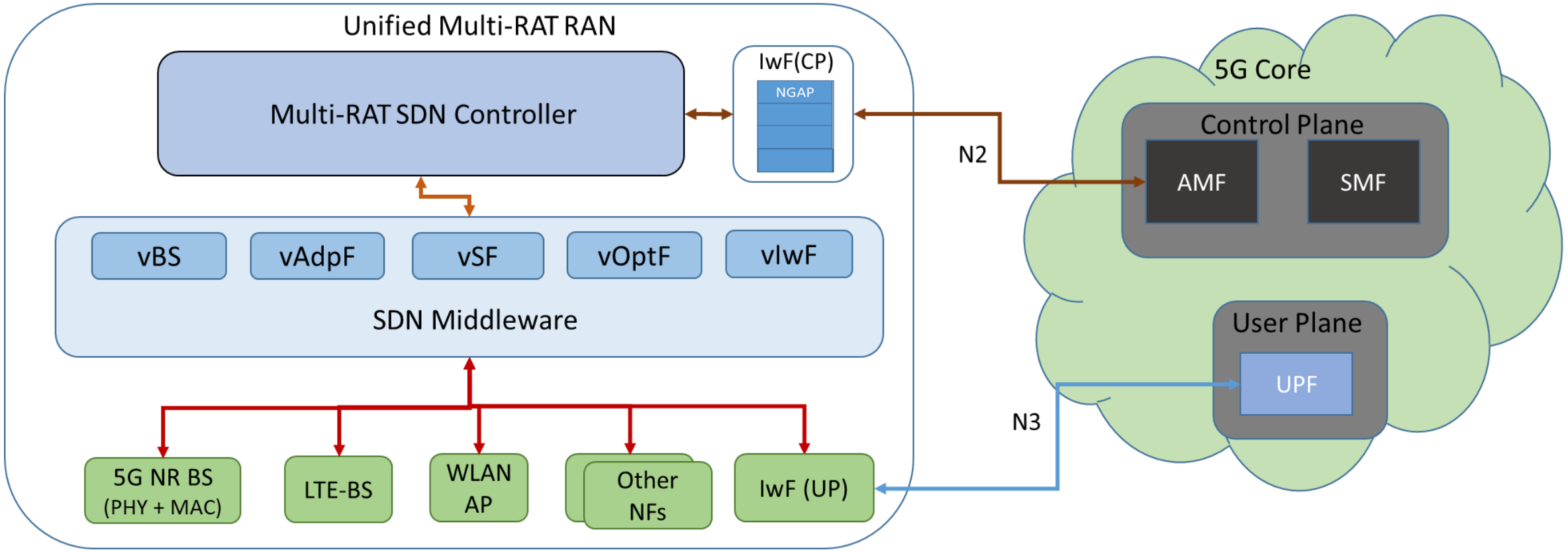
IEEE 1930.1 - Disaggregated Data Plane for Multi-RAT RAN

- Modular Data Plane Functions
- Medium Access Control Function - Base Station(BS)
  - Include MAC and lower Layers, e.g., Physical Layer
- Security Function (SF)
  - Encryption and Integrity Protection
- Optimization Function (OptF)
  - IP Header Compression etc.
- RAN Adaptation Function (AdpF)
  - Link Control, ARQ etc.
- Interworking Function (IWF)
  - Interworking with Core
  - In case of 5G - Comprise of N3 Interface Functions
- *A Controller may be responsible for controlling/managing a subset of modular functions*



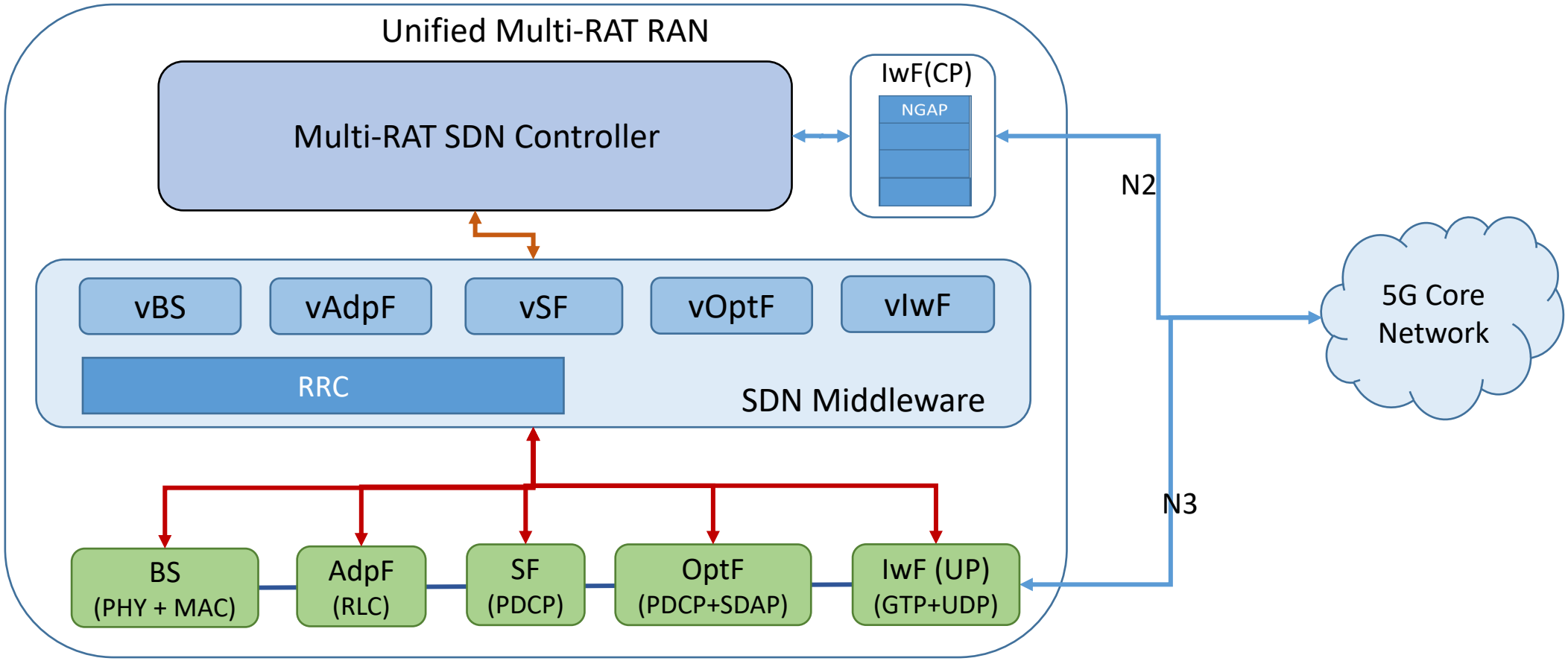
A Simplified Representation of 1930.1 Architecture

Unified Multi-RAT RAN (1930.1) Integrated with 5GS



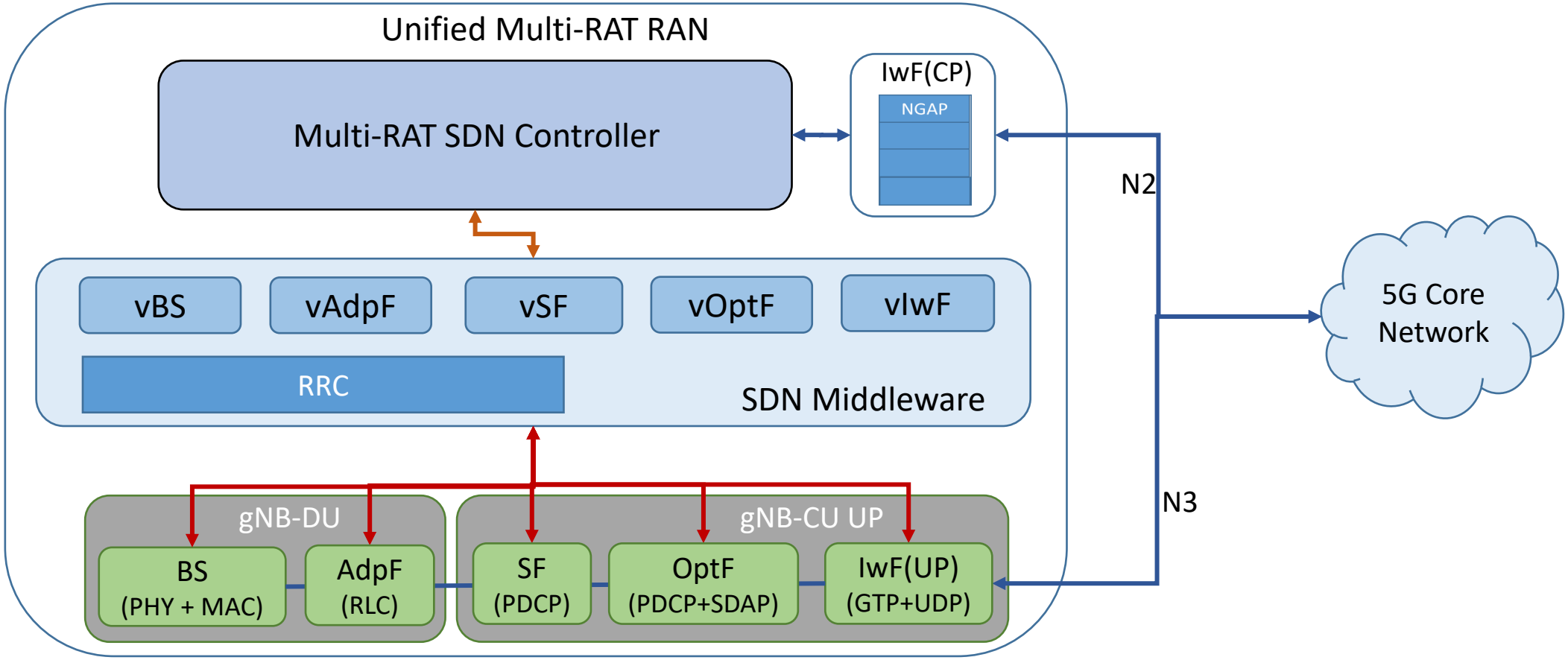
IEEE 1930.1 based 5G NG-RAN

- Limited changes in existing protocol layers
- Essentially a different placement of protocols layers
- Disaggregated NF based scheme



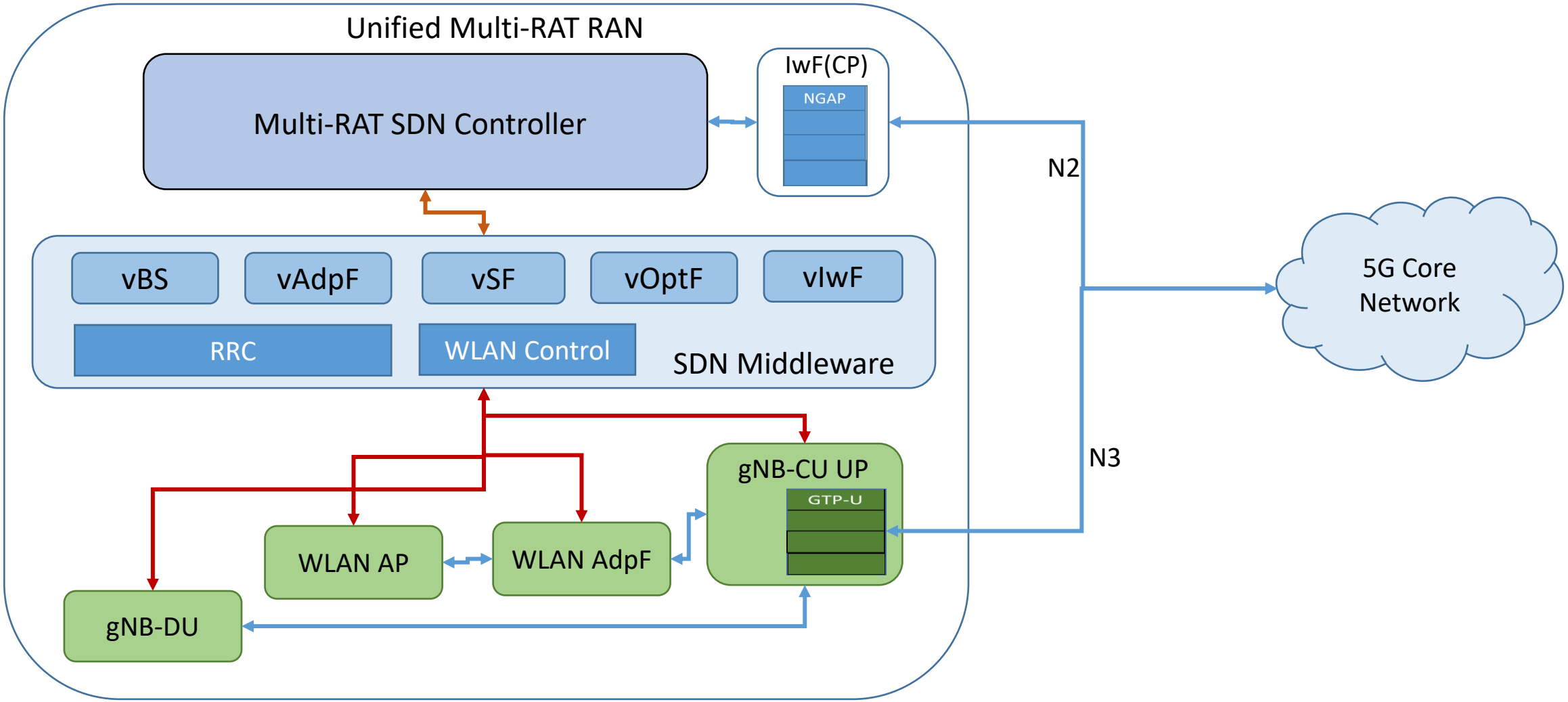
IEEE 1930.1 based 5G NG-RAN

- Another Scheme - Disaggregated NFs as part of existing nodes



IEEE 1930.1 – Multi-RAT RAN

Integrated WLAN & 5G NR



Thank you

Contact : pranavjha@ee.iitb.ac.in