Cellular Mobile Network Architecture for Beyond 5G: Learnings from IEEE P1930 and P2061

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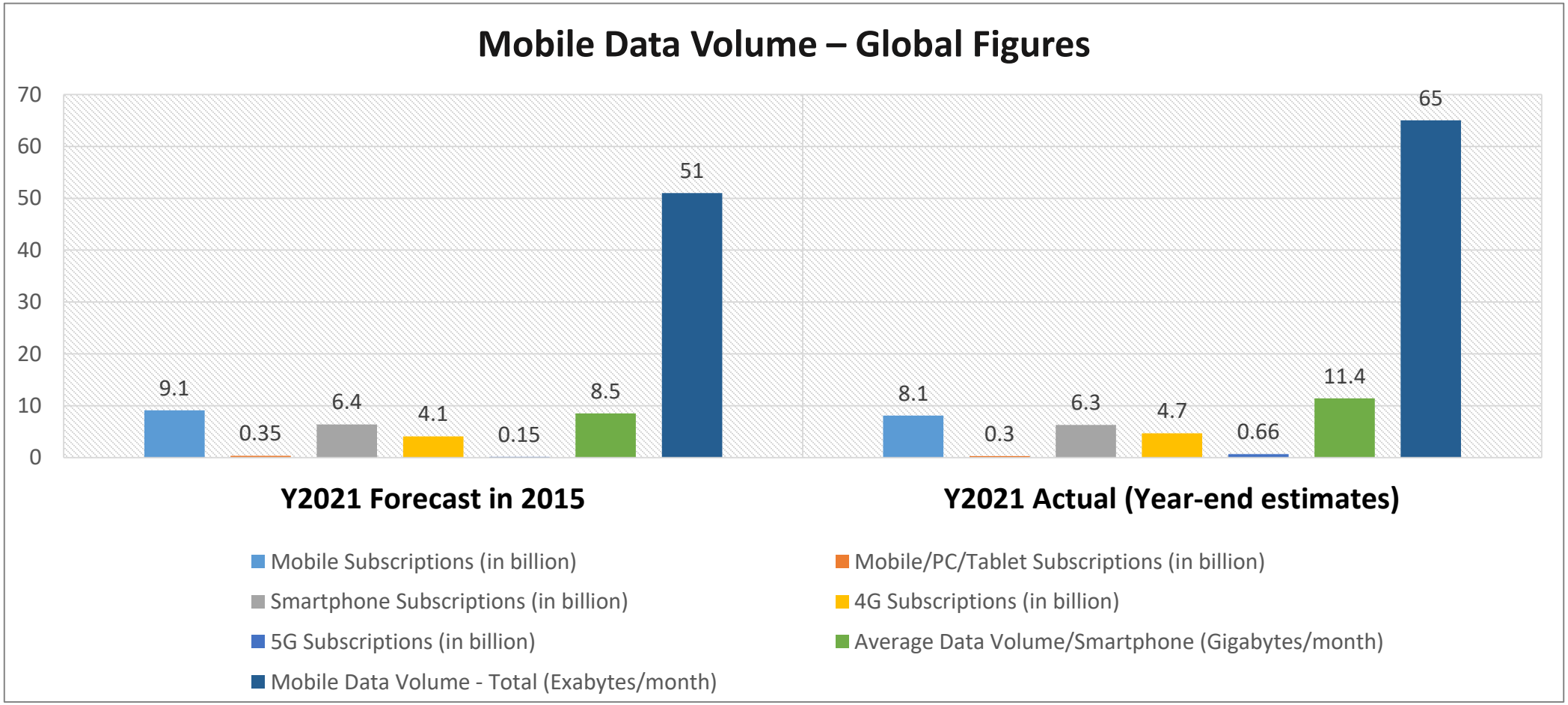
Agenda

- Enormous Growth in Mobile Data Traffic
- Coexistence of Multiple Radio Access
  - Non-3GPP Access (Wi-Fi/…)
  - 3GPP Access (LTE/NR/…)
- Limitations of 3GPP 5G System Architecture
- Introduction to IEEE P1930
- Introduction to IEEE P2061
- Towards beyond 5G network

Mobile Data Volume – 2021 (Global)



Actual Data volume exceed forecast

Courtesy : "Ericsson Mobility Report", Nov 2021

Mobile Data Volume – 2021 (India)

- Continued Growth in Mobile Data Consumption
  - Mobile Broadband Subscription – Sep 2021
    - 770 million
  - Current Mobile Data Volume
    - Year 2020 – 9.4 Exabytes/Month
    - Year 2021 – 12 Exabytes/Month
- Driving Factors
  - Increasing No of Smartphone Users
    - Increased data usage
  - Growing Footprint of Cellular Broadband Network (in Rural Areas too)

Courtesy : "Ericsson Mobility Report", Nov 2021
"Highlights of Telecom Subscription Data as on 30th September, 2021", TRAI, Govt of India

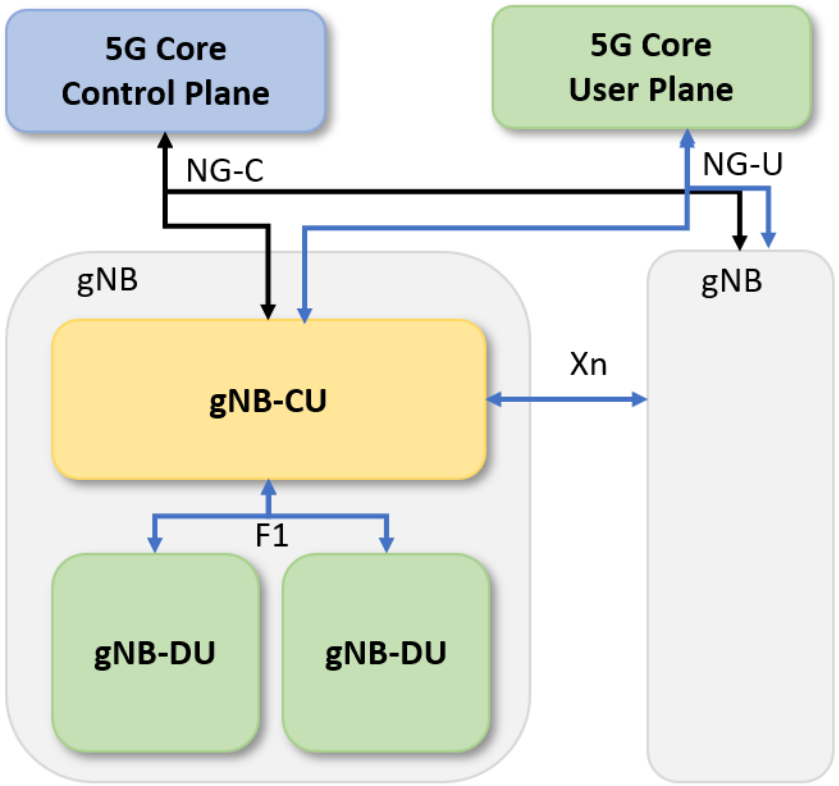
Mobile Data Volume in 2027 – Estimates for India

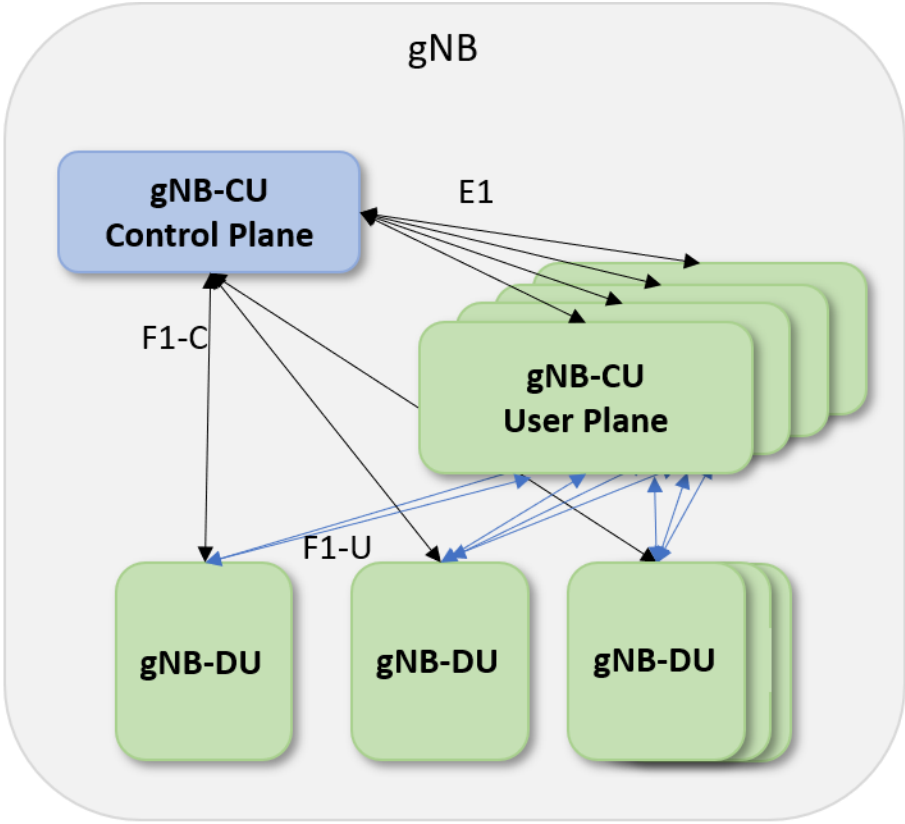
- Mobile Data Traffic Estimates for Users - India 2027
  - Most households likely to have mobile broadband access by 2027
  - Conservative Estimates
    - Assuming ~linear growth
  - Realistic Estimates
    - Inline with other forecasts
- Even a conservative estimate indicates
  - Huge data volume by 2027
  - ~23 Exabytes monthly
  - ~275 Exabytes annually
- Large no. of Data Plane Functions would be required for packet processing

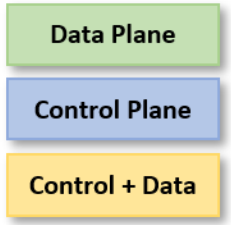
Mobile Data Traffic Estimation (India) (Human Users)

Parameter	Value	Unit	Remarks
India Population	1,40,00,00,000	-	Rough estimate (Internet Data)
Total No of housholds in the country	35,00,00,000	-	Average 4 persons/household
Conservative Estimate			
Contention Ratio	0.1	-	One family out of 10, accessing Internet at a time
Required Data Rate/household	2	Mbps	
Required Data Rate for the country (bits/s)	70,000	Gbps	
Monthly Data Requirement of the Country (total data)	23	Exabytes	
Realistic Estimate			
Contention Ratio	0.1	-	One family out of 10, accessing Internet at a time
Required Data Rate/household	5	Mbps	
Required Data Rate for the country (bits/s)	1,75,000	Gbps	
Monthly Data Requirement of the Country (total data)	57	Exabytes	

Existing 3GPP 5G Architecture
(Disaggregated RAN)

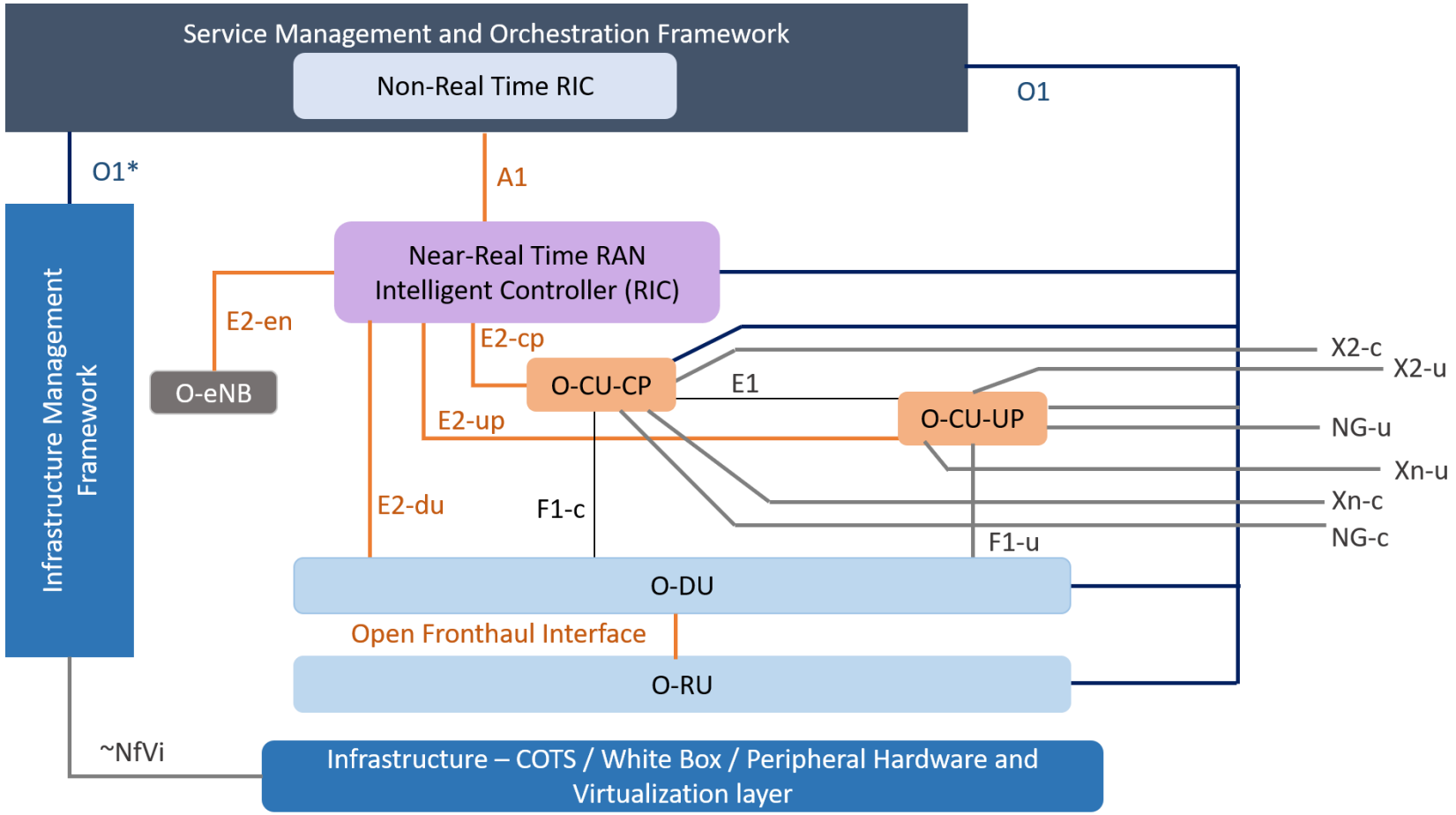






3GPP 5G RAN Architecture : Courtesy 3GPP TS 38.401

Existing 3GPP 5G Architecture (ORAN)
(Disaggregated RAN)



- An Architecture for Disaggregated RAN Proposed by 3GPP & ORAN
  - F1, E1, A1, E2, Fronthaul … (RU, DU, CU etc.)
- *Is this good enough*
  - *To handle the projected data volume?*
  - *For an increasingly Multi-RAT Access Network?*

Courtesy : https://docs.o-ran-sc.org/en/latest/architecture/architecture.html

Existing 3GPP 5G Architecture

Existing 3GPP 5G Architecture

1

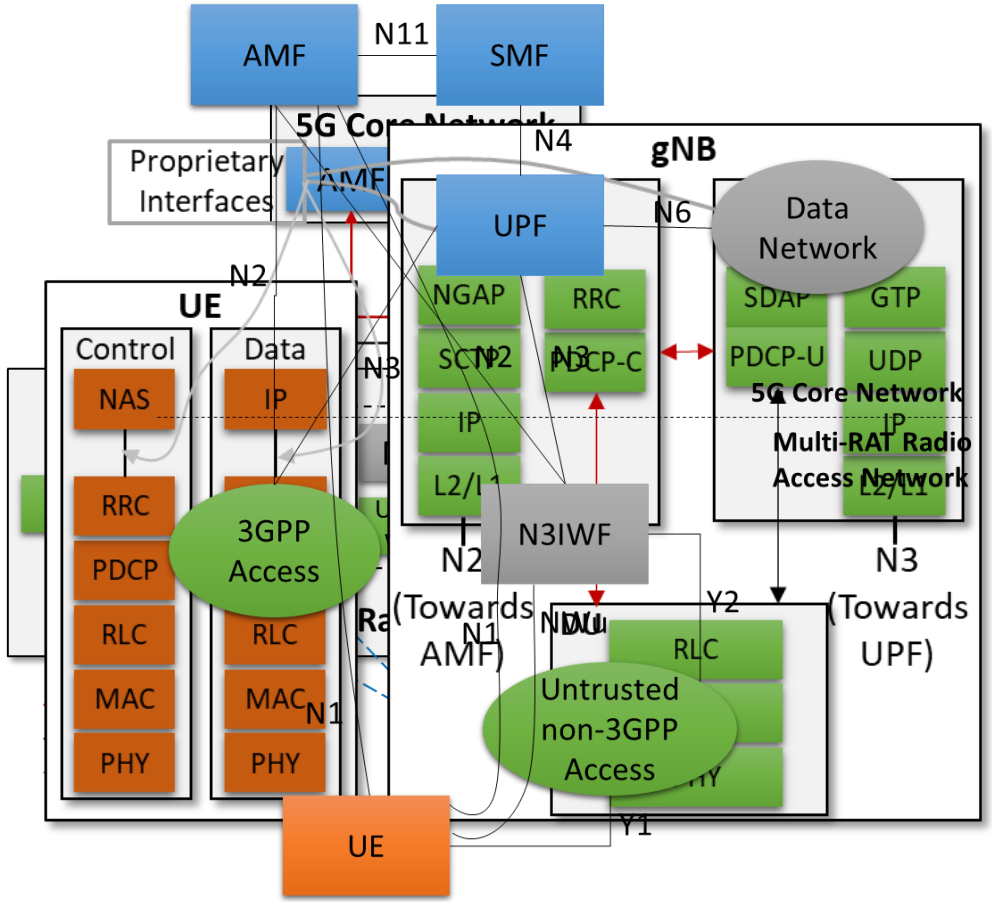
Converged Core - Multi-RAT Unification in Core Network

- **But no Unification at RAN Level**
- **Fragmented Decision Making in RAN**

2

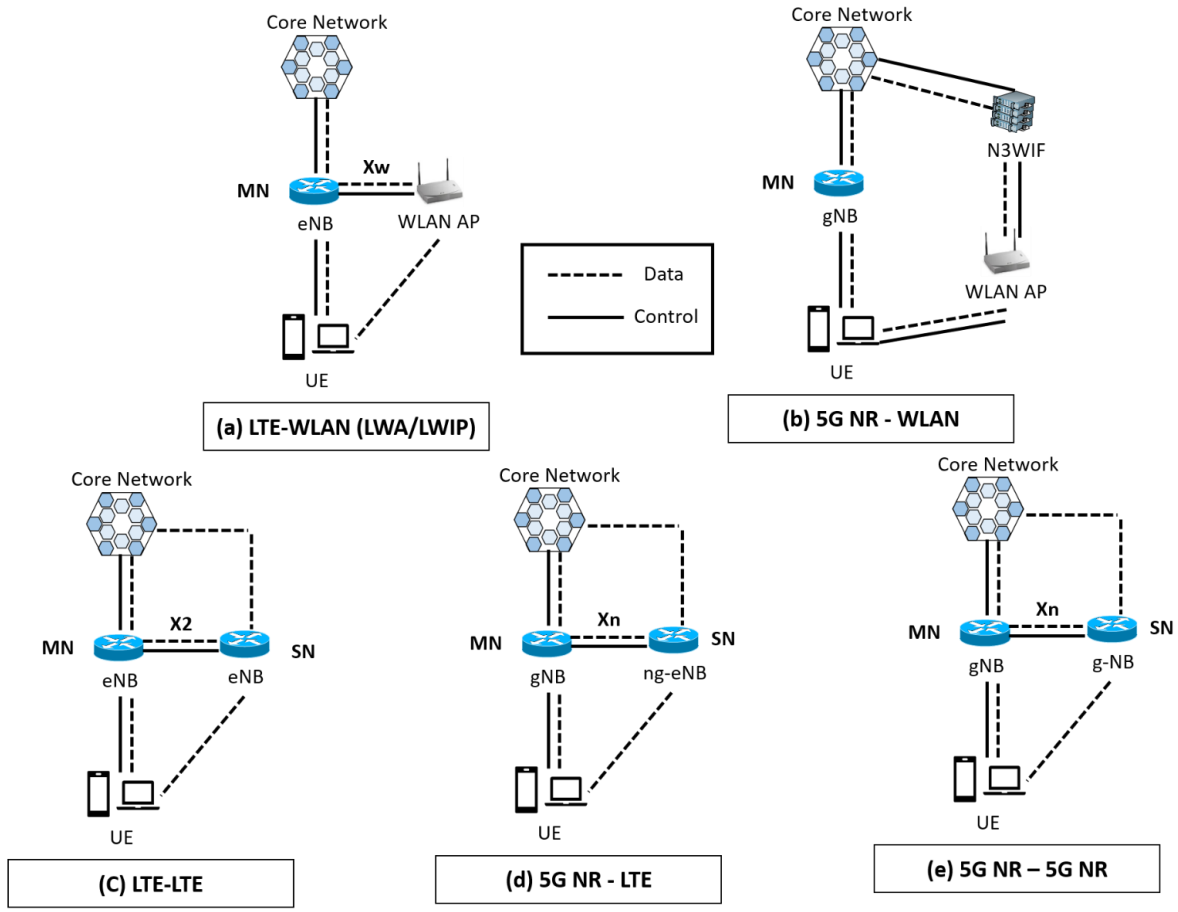
Tight and proprietary coupling between Radio and CN protocol stacks

- **RAT specific inter-working functions**
- **Loss of Flexibility – Can you connect 5G RAN to 4G Core or directly to Internet w/o Core?**



Existing 3GPP 5G Architecture -
Dual Connectivity & Load Balancing in RAN

- Dual Connectivity
  - Multiple RAT-Specific Variants
    - LTE-LTE DC, MR-DC, LTE-WLAN Aggregation (LWA)…
    - Differences across Variants
  - Distributed Scheme
    - Extensive coordination between eNBs/gNBs/WT(APs)
    - Implementation Complexity
- Load Balancing in RAN
  - Distributed Scheme across eNBs/gNBs
    - Load Information exchanged over X2/Xn
    - No Load exchange in the absence of X2/Xn
  - No Mechanism for Load Balancing across 3GPP and non-3GPP RATs
    - Wi-Fi AP and eNB/gNB
    - No mechanism available in 5GS



Dual Connectivity Variants

Existing 3GPP 5G Architecture -
Dual Connectivity & Load Balancing in RAN (contd.)

- Distributed Schemes
- RAT Specific Variants/Limitations
  - More than one variant
- No Load Balancing across 3GPP and non-3GPP RATs
- No network entity with a unified view of RAN resources
  - Fragmented RAN Control
  - LTE eNBs, WLAN APs/ACs, gNBs take decisions independently
  - Suboptimal Resource Utilization
  - Implementation Complexity

Architecture for beyond 5G – A few Points to Ponder

- How to Disaggregate Multi-RAT RAN?
- Should we have a Unified Multi-access RAN?
  - Unified Treatment of Dual Connectivity, Load Balancing, …?
- Should we decouple RAN from Core?
  - E.g., allow 5G NR RAN Connect directly to 4G Core
    - (for Non Standalone Deployment)
- Why do we need the Core?
  - Mobility is anchored at the Core
  - Authentication & Access Control
- A large % of mobile users may not be “mobile” any more
  - ***E.g., Rural Broadband Connectivity***
  - Can we bypass the core for such users?

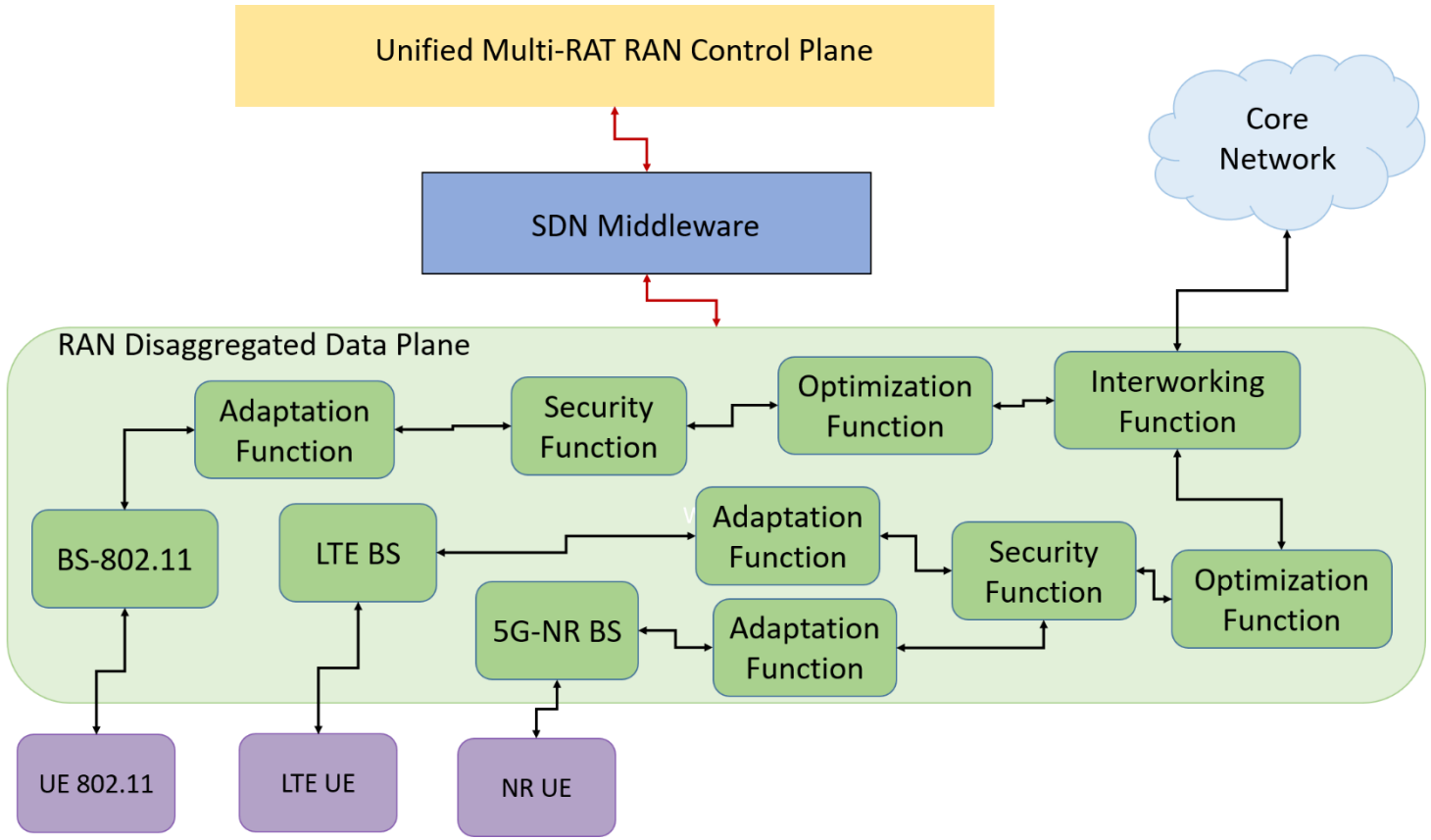
IEEE P1930.1 – A Scalable Architecture for Multi-RAT RAN

RAN Disaggregation and Unification

- RAN of most RATS perform similar functions in 5G
  - Security
  - Optimization (Header Compression etc.)
  - Interworking with Core
- Can we Disaggregate RAN along these simpler functions?
- Does it help in Load Management?
- Does it help in unified treatment of RATS?

IEEE P1930.1 - 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*

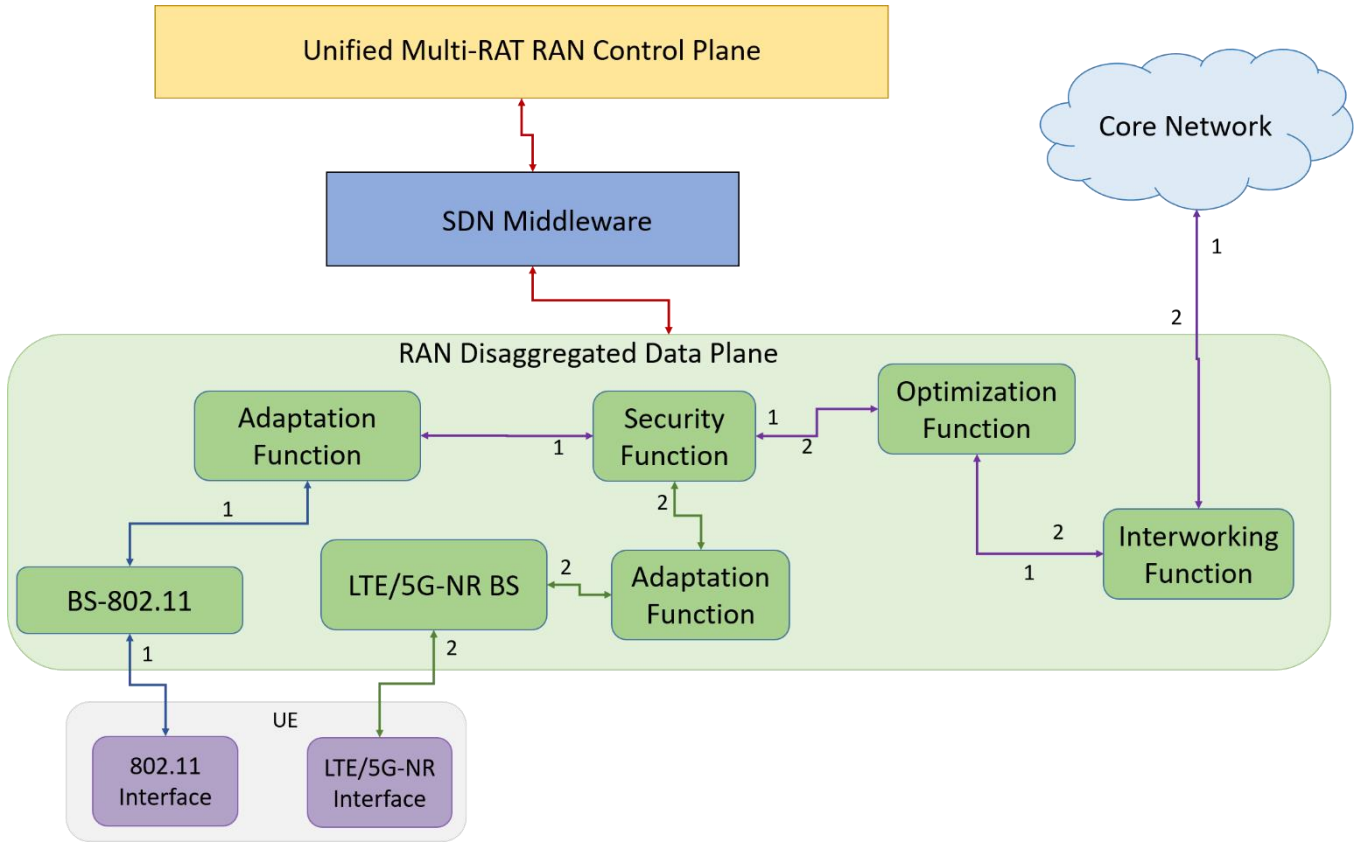


A Simplified Representation of P1930.1 Architecture

Reference :"IEEE P 1930.1", https://standards.ieee.org/project/1930_1.html
Draft complete, Balloting in progress

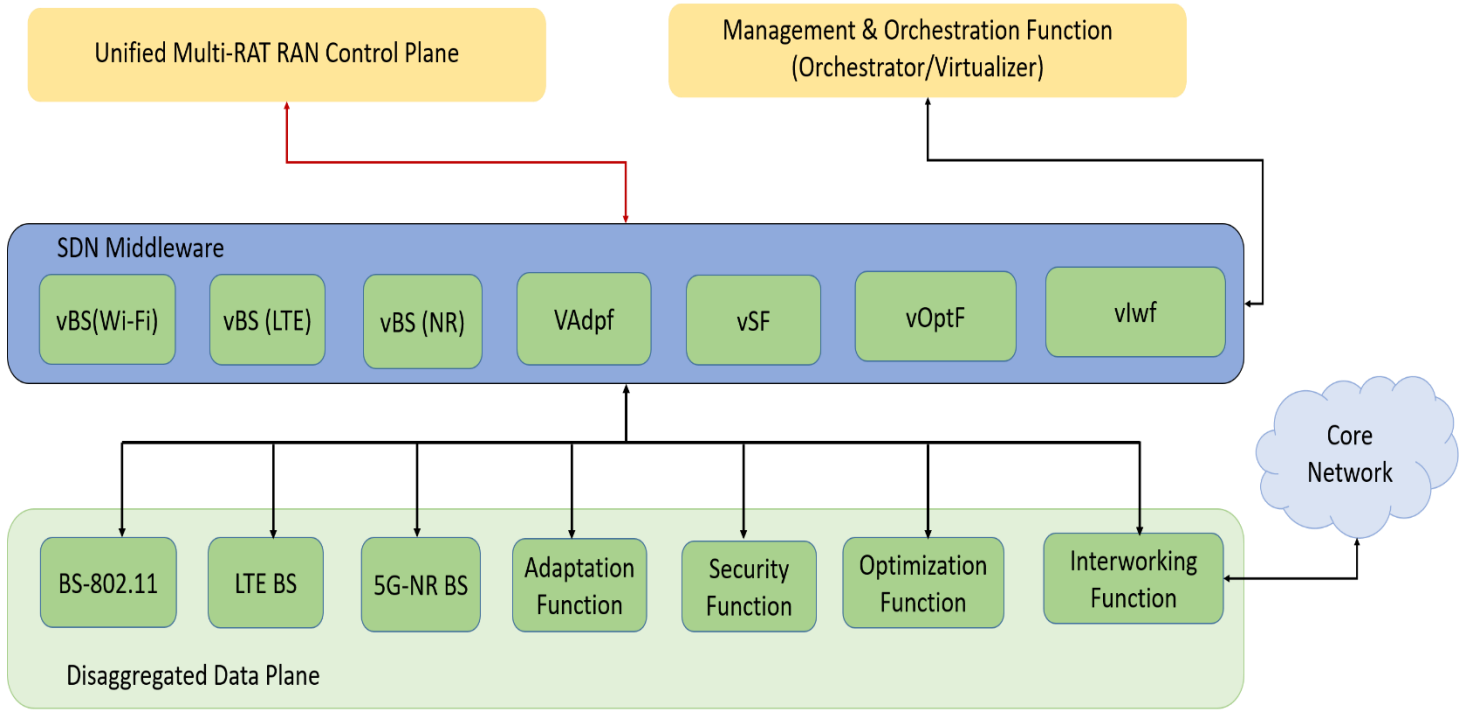
How does it help? IEEE P1930.1 & Dual Connectivity

- A UE connected to two Base Stations
- Traffic From Core - Via the same Interworking, Optimization and Security Functions
- Delivered through different BSs via RAT specific Adaptation (RLC…)
- Control Plane sets up Data path through AN elements
- Dual Connectivity across RATs supported with ease
  - LWA/LTE DC/MR-DC …
  - All DC variants



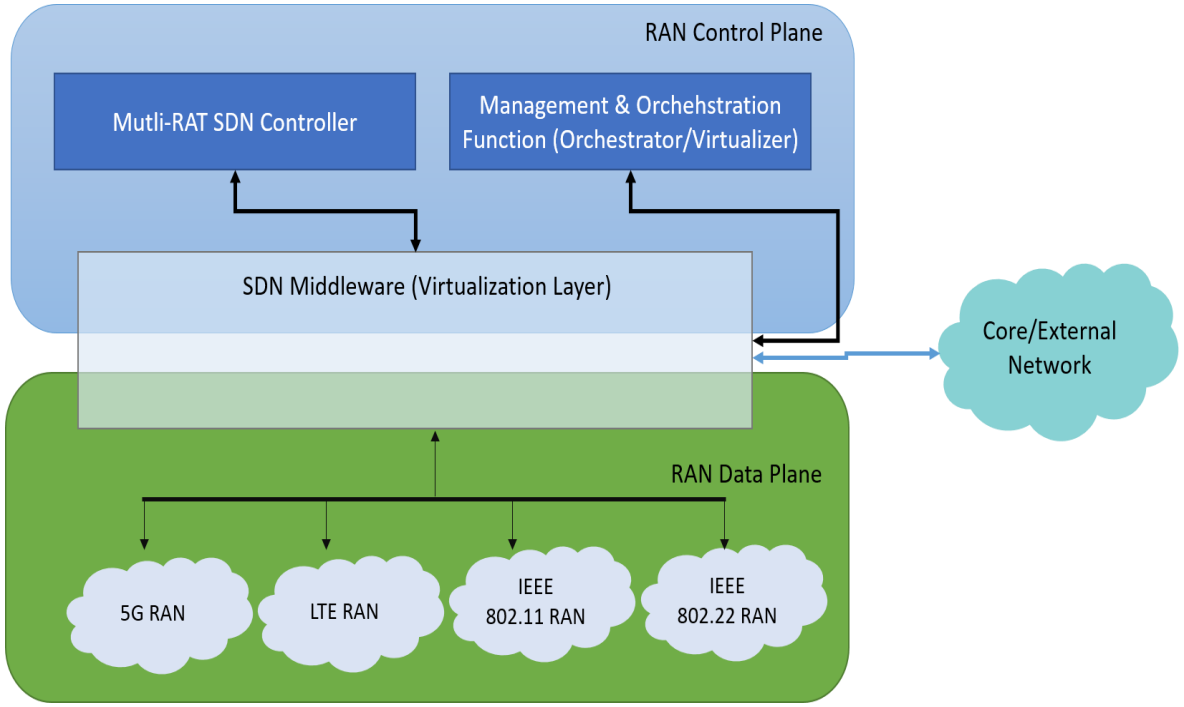
IEEE P1930.1 – Multi-RAT Unification/Virtualization

- An SDN Middleware
  - Between Control & Data Plane
  - To Virtualize and Unify Multi-RAT RAN Data Plane
- SDN Middleware
  - Abstract Information Model of the Data plane (through virtual entities)
  - Virtualize Underlying Data Plane Resources
  - Unify Control & Management of Multi-RAT RAN



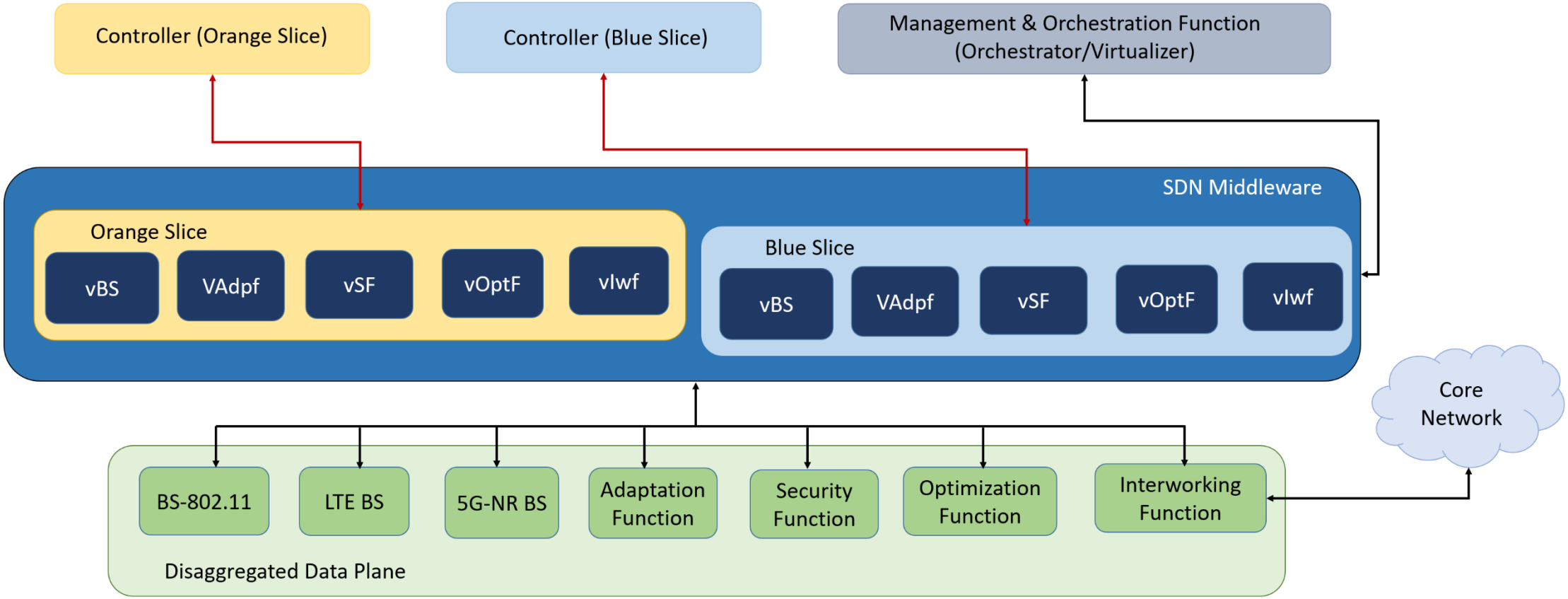
IEEE P1930.1 – Unified Multi-RAT RAN

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	• Access Points, Base Stations, Interworking Functions, …



IEEE P1930.1 Architecture - Slicing Support

- Virtual Entities Distributed Across Different Logical Networks
  - Network Slices Orchestrated by the Orchestration Function
- Every Slice Controlled by a Different SDN Controller



IEEE P1930.1 - Summary

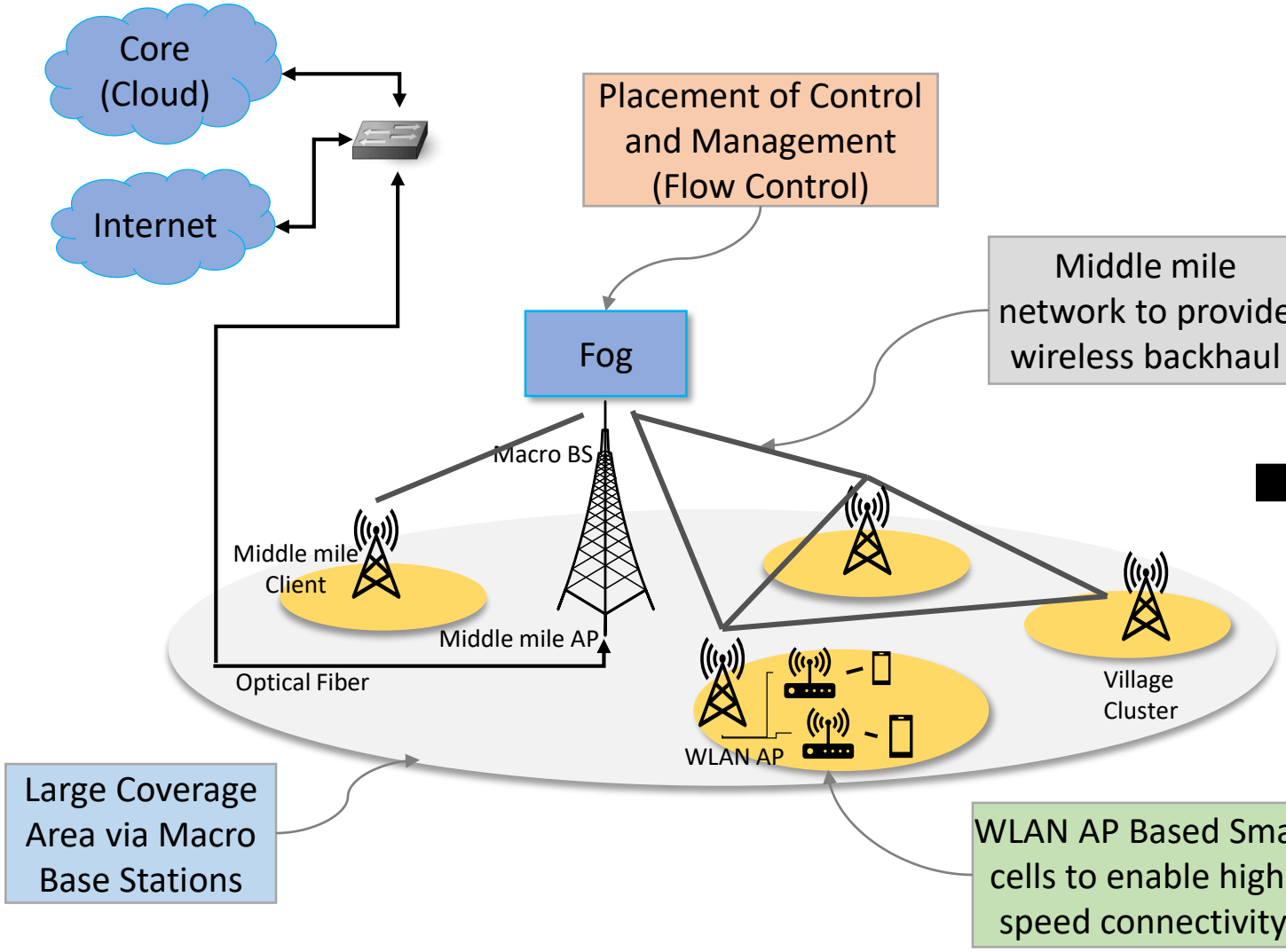
- Modular, Re-usable Data Plane Functions
  - Scalable Access Network
- Virtualization of Data Plane through SDN Middleware
  - Abstract Information Model for the Controller
- Unified Multi-RAT Control
  - Unification of RATS at RAN level
- Improved Performance
  - Better Load Distribution in RAN
  - Across granular functions
  - Decision taken by Multi-RAT Controller
- Ease of Implementation, Simplicity, Flexibility
  - Dual Connectivity
  - Network Slicing

IEEE P2061 - Frugal 5G Network

Rethinking 5G Requirements for Rural Areas

- Affordability
- Limited need for mobility
- Large coverage area support
- Sparsely Populated areas with Clusters of Settlement
- Energy efficient solution
- Localized communication and local content generation/storage
- Ease of Manageability

IEEE P2061 Frugal 5G Networks

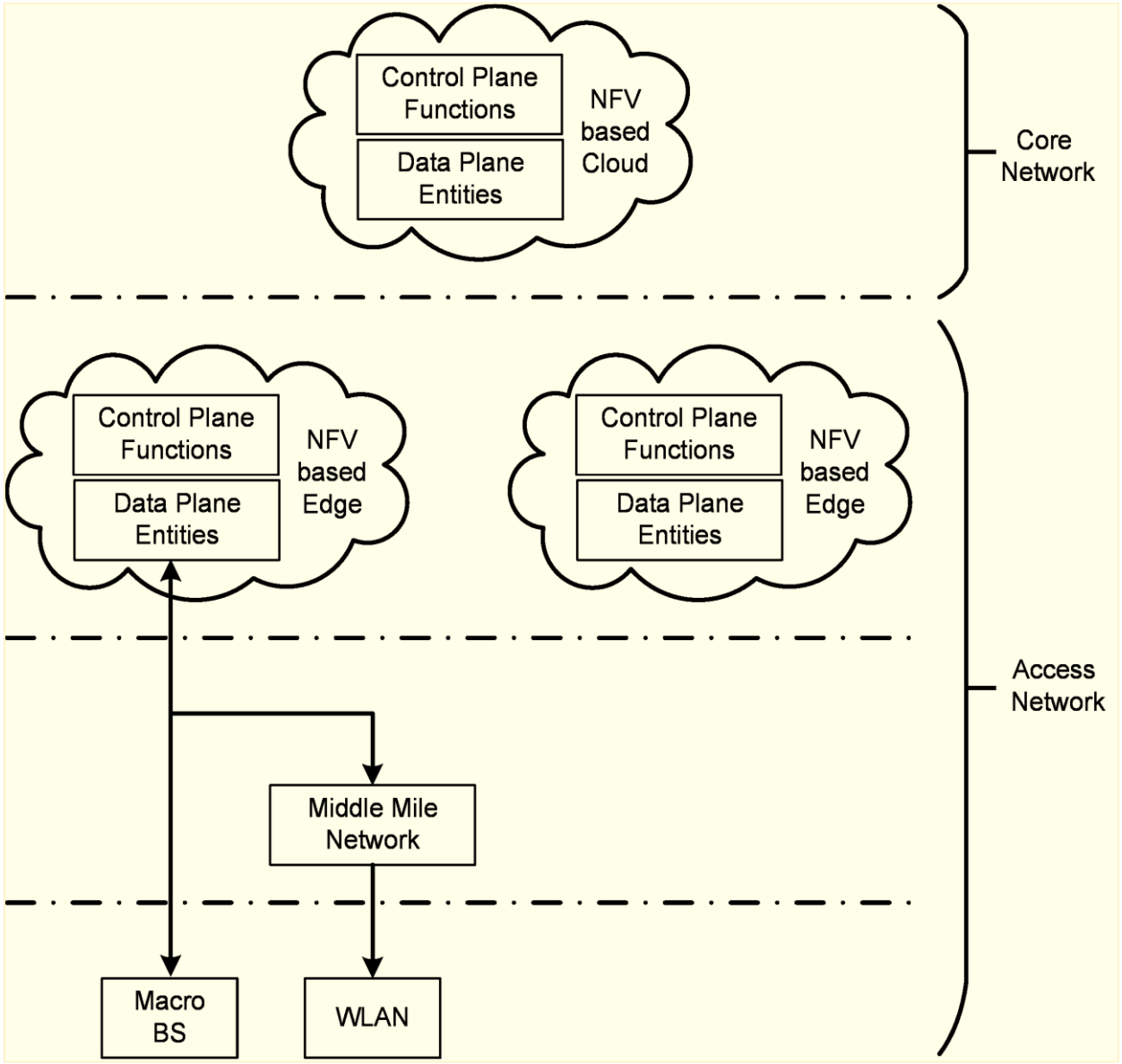


Frugal 5G Networks (IEEE P2061)

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

Source: Khaturia M, Jha P and Karandikar A, IEEE Communication Standards Magazine, June 2020

IEEE P2061 Frugal 5G Network – Key Attributes



Flexible Implementation

- Usage of both Macro Cell and WLAN access
- Wireless Middle-mile to carry WLAN traffic from villages to PoP

Intelligence at the Edge

- Local Communication Support
- Direct Internet Connectivity from RAN (bypassing Core)

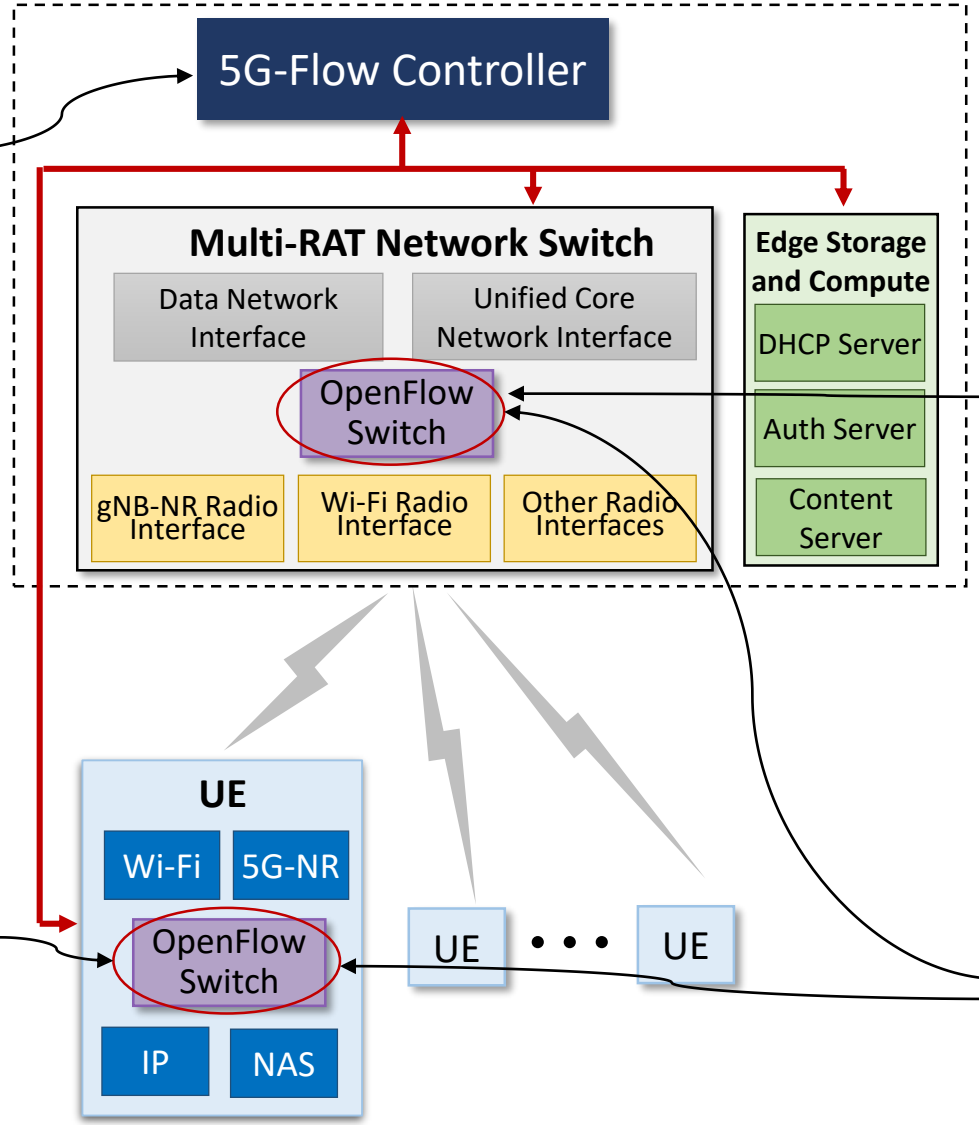
SDN based Unified Control

- RAT agnostic Unified Interface towards Core
- Decoupling Core from RAN
- Unified multi-access control at the edge

5G-Flow : Realizing Frugal 5G Network

SDN based RAT agnostic controller

- Unified RAN level control & management



Introduction of OpenFlow switches at network

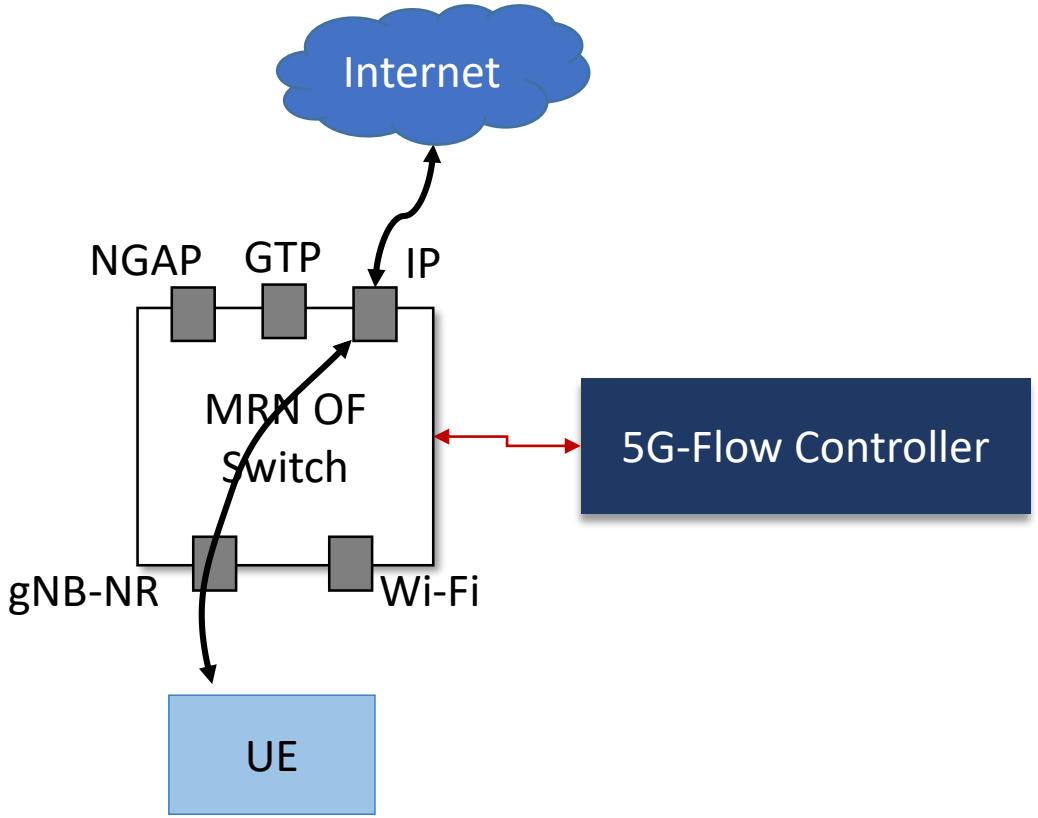
- Replaces proprietary interfaces
- Enables unified interworking

Introduction of OpenFlow switches at UE

- Replaces proprietary interfaces

Decouples UE's communication with CN from its communication with RAN

5G-Flow Appl. - Direct Connectivity to Internet



Existing cellular technologies, e.g., LTE/5G NR requires support of Core Network (CN)

- Can not work in a standalone manner without CN

5G-Flow Network architecture allows usage of cellular technologies (5G NR…) without involving CN

- UE's connectivity with RAN is decoupled from it's connectivity with CN
- 5G-Flow controller sets up the flow entry and creates radio bearer at RAN to enable direct connectivity with Internet

Source: Khaturia M, Jha P and Karandikar A, Journal of Computer Networks (2021)

5G-Flow - Summary

- (Modified) OpenFlow can be used to **decouple RAN from Core**
  - Though Not necessary to use OpenFlow
    - Other protocols/mechanism can also be used
  - Existing 3GPP protocols can continue to be used w/o much changes
  - OpenFlow augments the existing architecture without modifying them
- Flexible Mobile Network Architecture
  - Any RAN can be used with any Core
  - Use Core Selectively
    - Only for mobile users
    - For Authentication…
- Other Use Cases
  - Direct Connectivity to DN (Internet…) from RAN
  - (Simpler) NSA Implementation
  - Captive Networks

IEEE P1930 & P2061 – Key Design Principles

- Disaggregated Multi-RAT RAN
  - Modular and Reusable Network Functions
  - Scalable Architecture
- Usage of SDN Paradigm
  - Separation of Control and Data Plane in RAN
  - Virtualization of RAN Resources through an SDN Middleware
  - Abstract Information Model of RAN Data Plane
- Unified Multi-RAT RAN Control
- Replacing Proprietary Interface between Radio and CN Interfaces
  - By OpenFlow Switches
- Decoupled RAN and Core
  - Flexible Architecture – Interworking of any RAN with any Core
  - Direct Connectivity from RAN to Internet (bypassing Core) for stationary/nomadic users
- RAT Agnostic Common Interworking Function towards Core

Way to Design Future Next Generation Cellular Mobile Network Architecture

THANK YOU