6G Vision : Requirements, Spectrum and Architectural View

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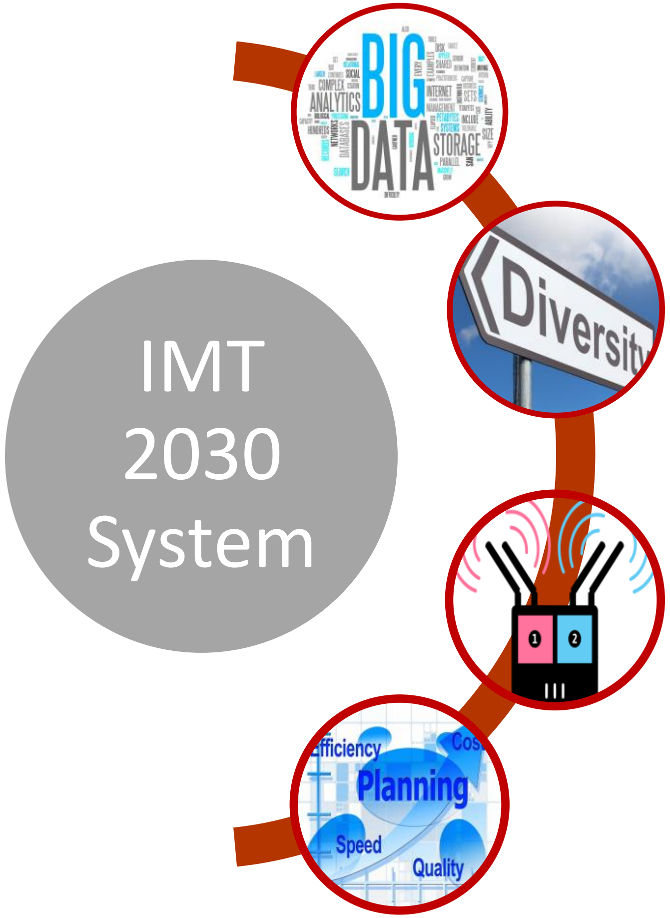
Agenda

- IMT 2030 (6G) System Requirements
- Spectrum for 6G
- Architecture
  - Limitations of 5G System Architecture
  - Points to Ponder
  - 6G System Architecture - Some Thoughts

6G Requirements

Requirements for 6G System



- Huge Data Volume
  - Mobile Networks – Primary vehicle for Connectivity
- Massive Connectivity
  - Massive signalling load
- Service (Use Case) Diversity
  - "Very High Throughput" to "Very Low Throughput" Applications
  - "Latency Tolerant" to "Stringent Low Latency" Applications
- Diverse Set of Users
  - Stationary Users, Mobile Users, Users moving at very high speeds
  - Connectivity for everything/everywhere
- A Variety of Access Technologies
  - Cellular Access, WLANs, Satellite Access…
  - Small Cells, Large Cells
  - Unicast, Broadcast
- Efficient & Cost-effective Service Delivery
  - Sustainability, Energy Efficiency

Mobile Data Volume in 2029 – Estimates for India

- Mobile Data Traffic Estimates for India - 2029
  - Most households likely to have mobile broadband access
  - Conservative Estimates
    - ~62 Exabytes/month
  - Realistic Estimates
    - ~92 Exabytes/month
- Even a conservative estimate indicates
  - Huge data volume by 2029
  - ~62 Exabytes monthly
  - ~744 Exabytes annually

Mobile Data Traffic Estimation (India) (Human users)			
Parameter	**Value**	**Unit**	**Remarks**
India Population	1,50,00,00,000	-	Rough estimate (Internet Data)
Total No of housholds in the country	37,50,00,000	-	Average 4 persons/household
Conservative Estimate			
Contention Ratio	0.1	-	One family out of 10, accessing Internet at a time
Required Data Rate/household	5	Mbps	
Required Data Rate for the country (bits/s)	1,87,500	Gbps	
Monthly Data Requirement of the Country (total data)	62	Exabytes	
Realistic Estimate			
Contention Ratio	0.1	-	One family out of 10, accessing Internet at a time
Required Data Rate/household	7.5	Mbps	
Required Data Rate for the country (bits/s)	2,81,250	Gbps	
Monthly Data Requirement of the Country (total data)	92	Exabytes	

The huge data traffic coupled with Massive and Ubiquitous Connectivity scenarios would generate a sizeable signalling load and put significant pressure on control plane functions

6G Architecture

5G Network Architecture – Some Limitations

3GPP 5G Architecture

1 **Converged Core - Multi-RAT Unification in Core**

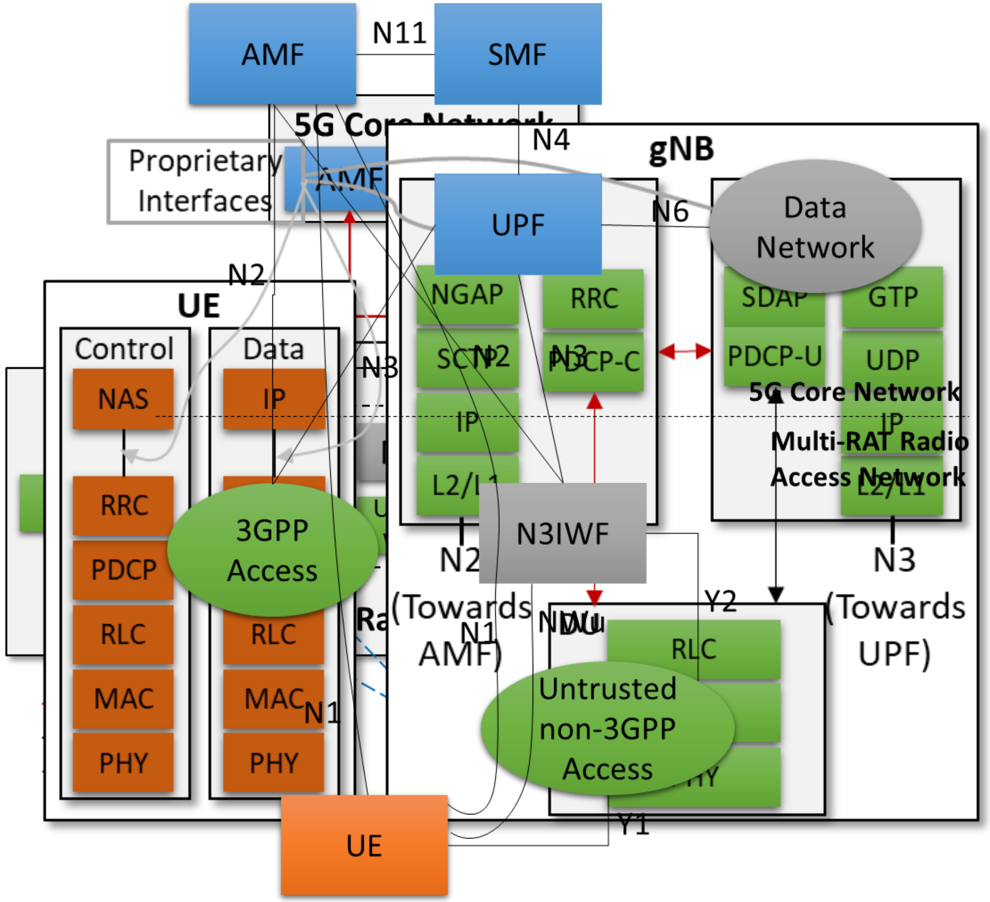
- But No Unification at RAN Level
- Fragmented Decision Making in RAN

2 **Tight and proprietary coupling between Radio and CN protocol stacks**

- Loss of Flexibility – Can you connect 5G RAN to 4G Core or directly to Internet w/o Core?

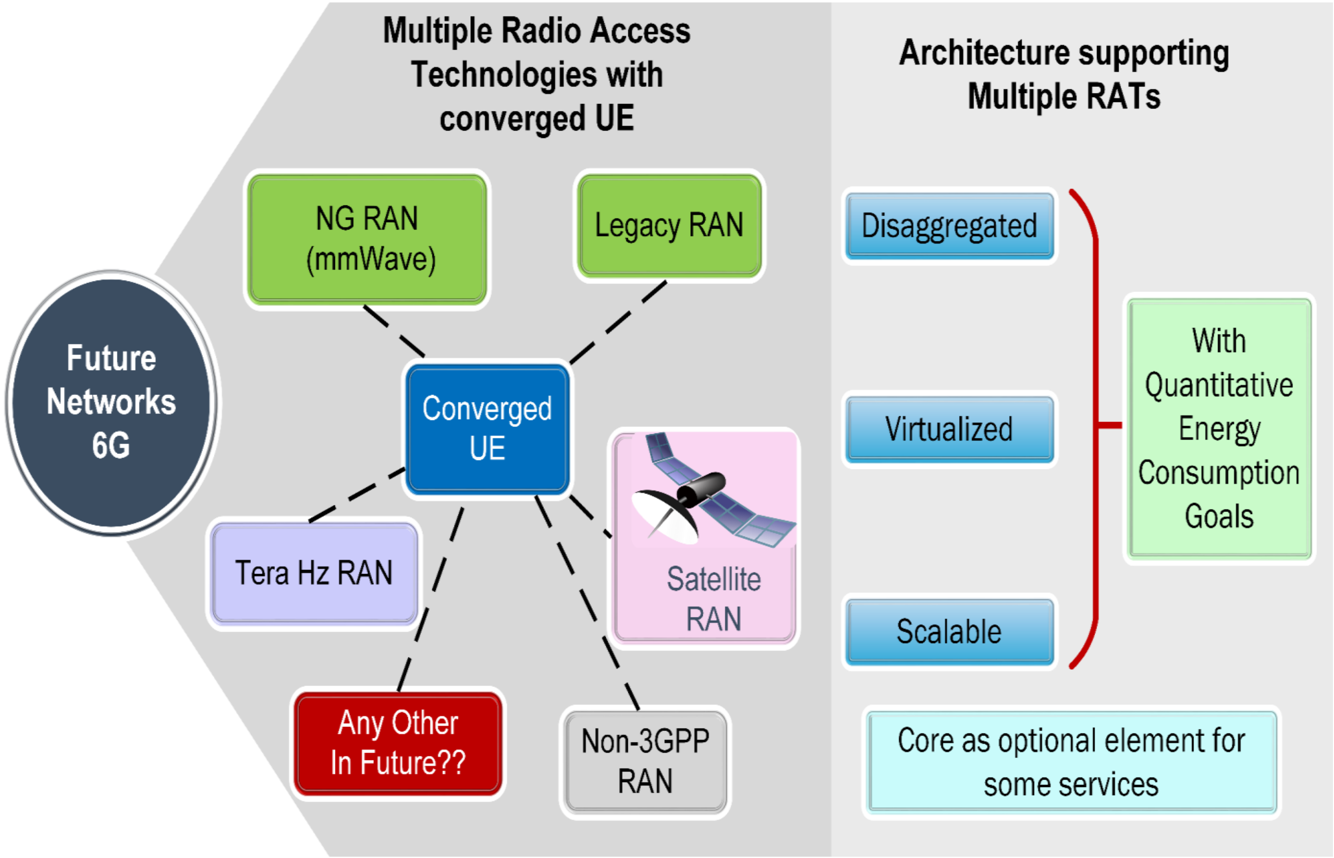
3 **Service/User Agnostic Handling**

- Fixed Route/Path for Control & Data flows
- Usage of Core Network in every Scenario
  - Usage of Tunnels for all data flows
- No use case specific variation in Protocol Behaviour



Architecture for 6G - Points to Ponder (1/3)

- Scalable Architecture
  - High signalling load – How to avoid making control plane a bottleneck?
    - Further Disaggregation of Control Plane
    - Decoupling of Signalling Handling and User Plane Control
    - Decoupling of Signalling and Data
  - Further Disaggregation of User Plane
- Unified Multi-access RAN
  - Multi-Connectivity & Multi-access Convergence
  - Unified Treatment of Dual Connectivity …
- Usage of SDN Paradigm

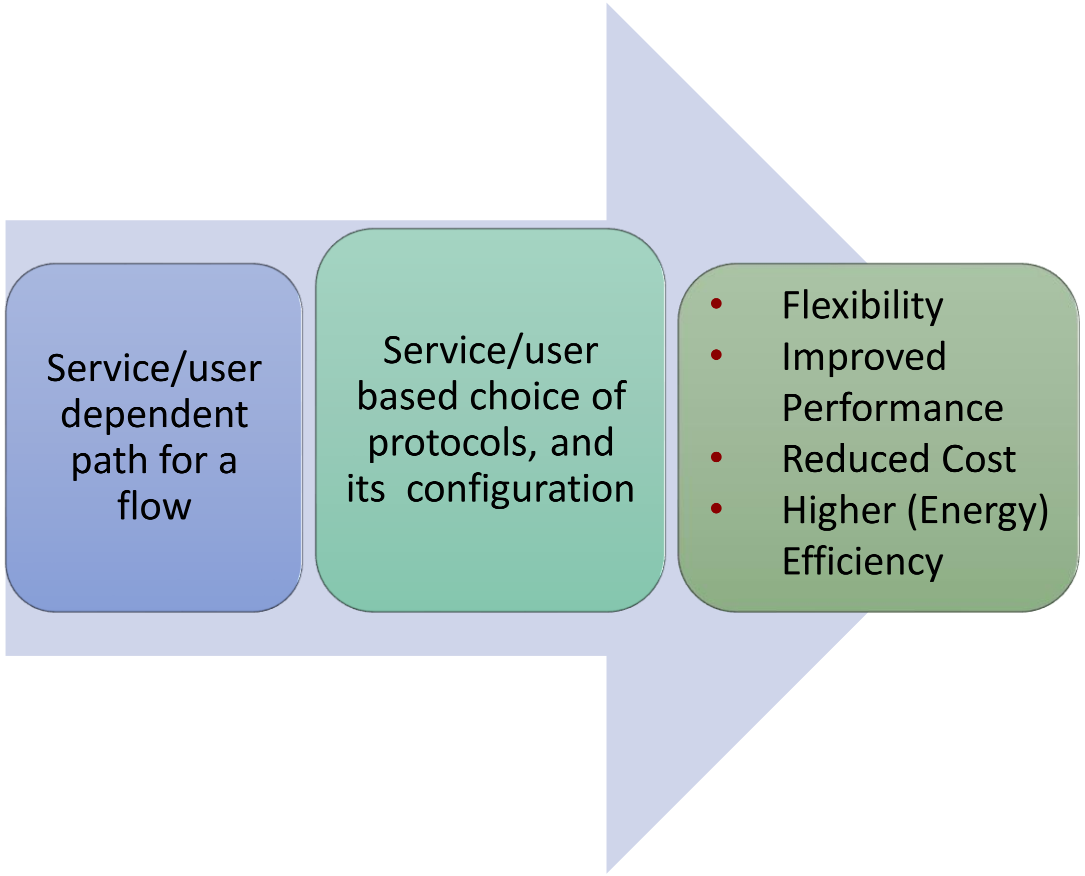


Architecture for 6G - Points to Ponder (2/3)

- Need for core in cellular network
  - Mobility - Anchored in Core
  - Also Authentication, Access Control…
- A large % of mobile network users not "mobile"
  - Rural Broadband Connectivity, IoT …
  - **Can we bypass core for such users?**
  - Direct Connectivity to Internet from RAN
- Should we decouple RAN from Core?
  - Interworking of any RAN with any Core
    - Non Standalone Architecture requires 5G RAN to interwork with 4G Core
      - Achieved with the help of 4G-RAN
      - Not possible w/o 4G RAN
  - Connect future 6G RAN to 5G Core

Architecture for 6G - Points to Ponder (3/3)

- Flexible Architecture
  - Flexible Protocol Structure
    - Not rigidly layered
    - Tunnelling protocols not required for all users
  - Virtualization of Network Resources
    - Better support for Network Slicing,…
- Energy Efficient Networks
- Intelligence-driven Network
  - Optimization of Services/Applications
    - AI/ML Model/Data Distribution
    - Federated Learning
  - AI-powered Network Design & Optimization
    - AI-powered Optimization
    - AI-powered Protocol Stacks
    - Learning-oriented Network Design



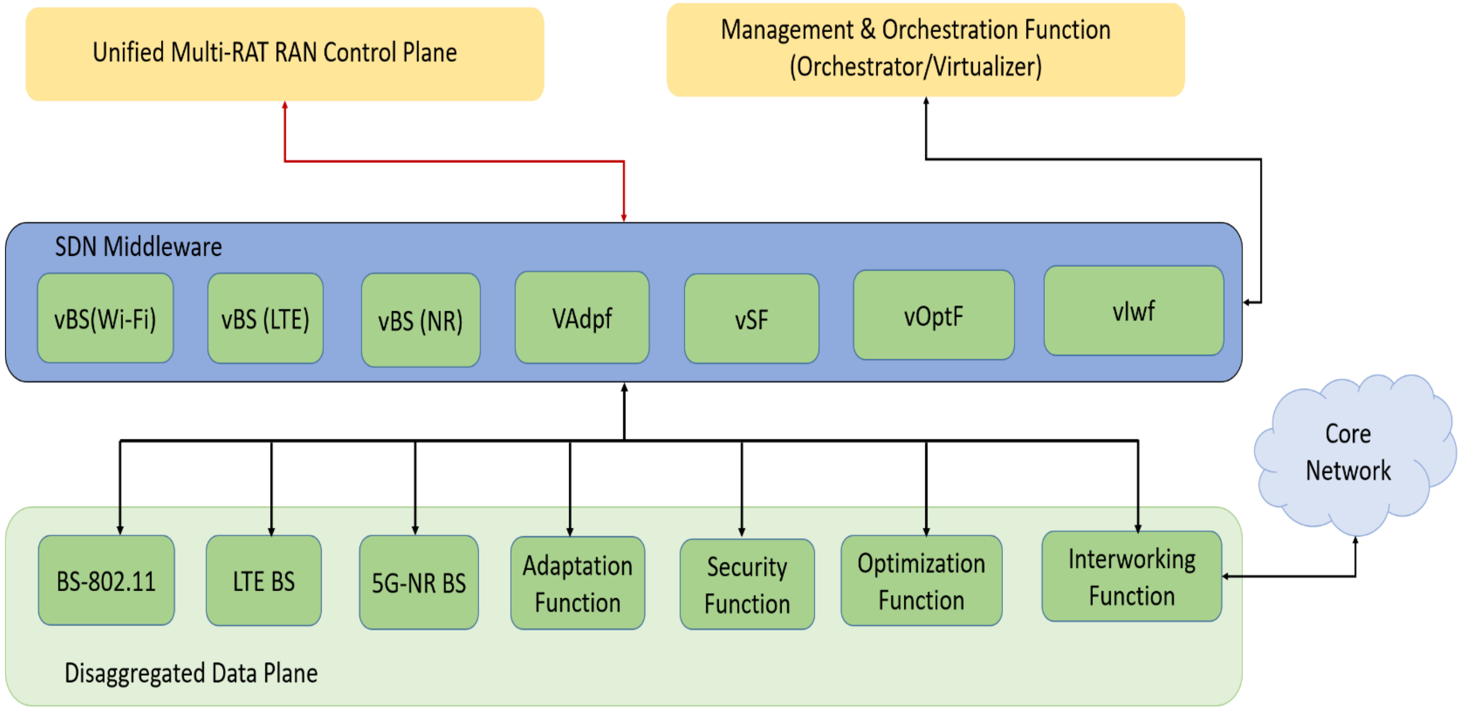
6G System Architecture – A few proposals

Scalable Architecture - RAN User(Data) Plane Disaggregation

- RAN User (Data) Plane of most RATS perform similar functions in 5G
  - Radio Tx/Rx
  - PHY & MAC
  - Link Adaptation
  - Security (Encryption)
  - Optimization - Header Compression …
  - Interworking with Core
- Can we Disaggregate RAN along these simpler functions?
- Does it help in unified treatment of RATs?
- Does it help in Load Management, Dual Connectivity?

Unification & Virtualization of Disaggregated Multi-RAT RAN

- Virtualization Layer (SDN Middleware)
  - A Layer between Control & Data Plane
  - Abstract Information Model of Multi-RAT RAN Data plane
    - Virtualize Underlying Data Plane
    - Modularized Information Model
  - Unify Control & Management of Multi-RAT RAN
- Unified Control Plane
  - Usage of SDN Technology
  - Controls RAN Data Plane Functions of all RATS
  - SDN Middleware Abstraction helps in Unified Control
- Improved handling of
  - Load balancing, Dual Connectivity, Network Slicing



Courtesy : IEEE 1930.1-2022

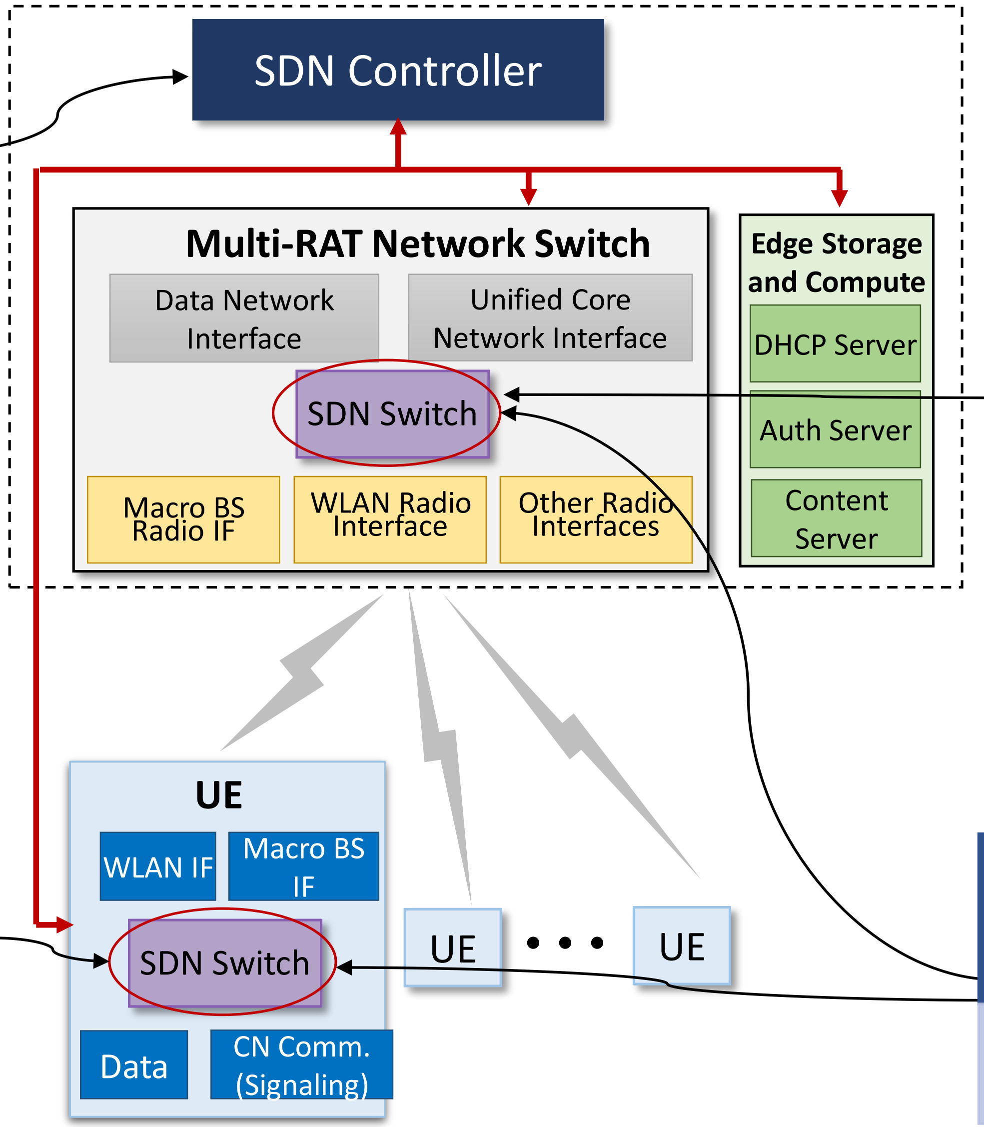
5G-Flow - Core Bypass using SDN

SDN based RAT agnostic controller

- Unified RAN level control & management

Introduction of SDN switches at UE

- Replaces proprietary interfaces



Introduction of SDN switches and controller in access network

- Replaces proprietary interfaces
- Enables unified interworking

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

- UE - CN communication - Overlay over UE - RAN communication

5G-Serv : 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?
  - Leads - Further Disaggregation of Control Plane

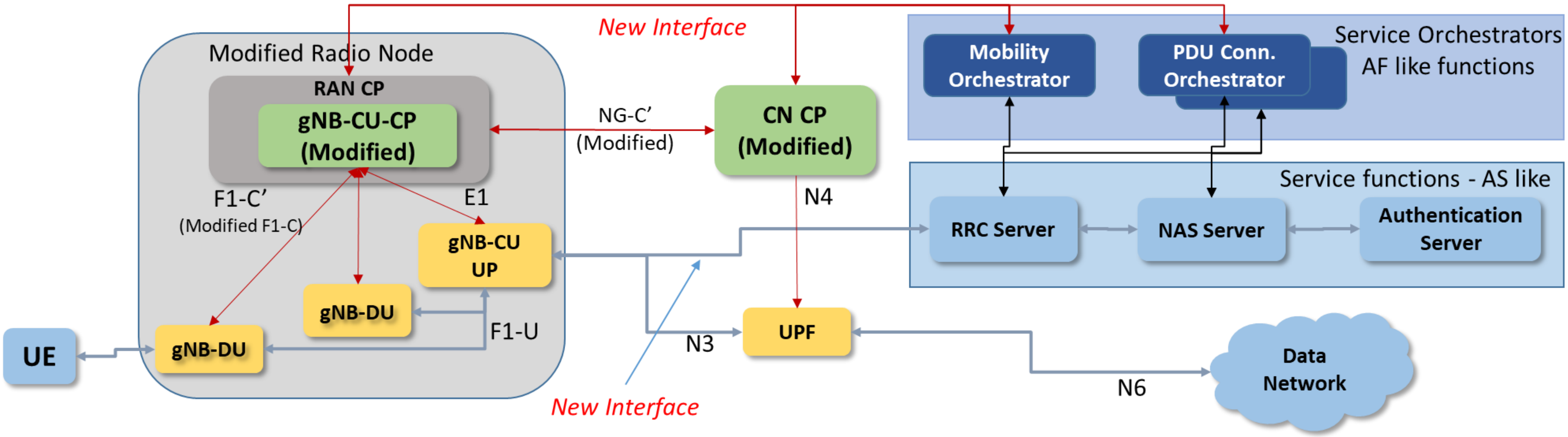
Reference: “5G-Serv: Decoupling User Control and Network Control in the 3GPP 5G Network”; Meghna Khaturia, Akshatha M Nayak, Pranav Jha, Abhay Karandikar, ICIN 2021

Recommendation ITU-T Y.2325: “Architectural evolution for NGN control plane by applying SDN technology”

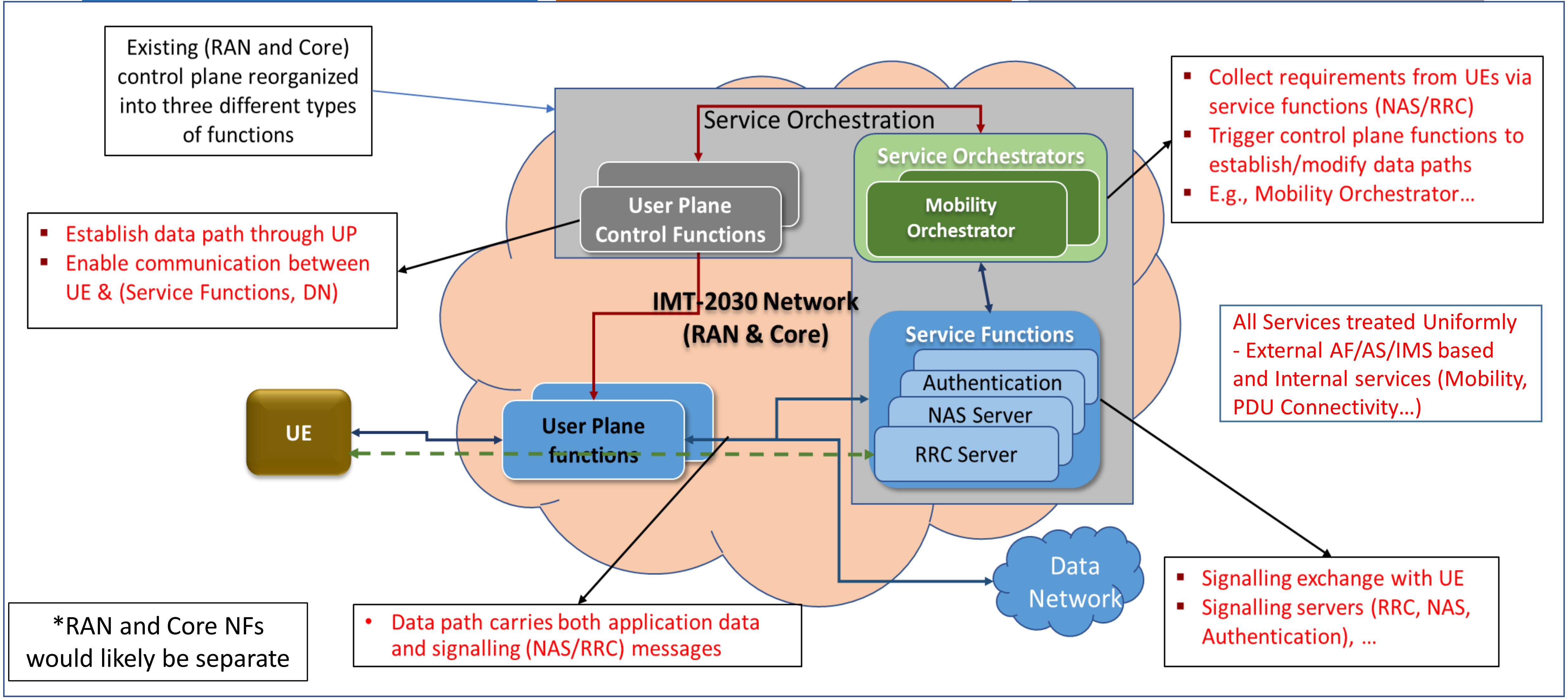
5G-Serv : Impact on RAN+CN Control Plane

- 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

Leads to a Generic Architecture



5G-Serv : A Service Driven Architecture for IMT-2030



5G-Serv : Highlights

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

Conclusion

Motivation

- Massive & Ubiquitous connectivity
- High speed data
- Sensing, Intelligence
- Sustainability

Spectrum

- THz bands
- More options in low and mid bands
- Expanding the spectrum horizon with harmonization

Design principles

- Service driven core
- Multiple RATs
- Energy awareness
- AI/ML driven design
- Core-free services

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THANK YOU