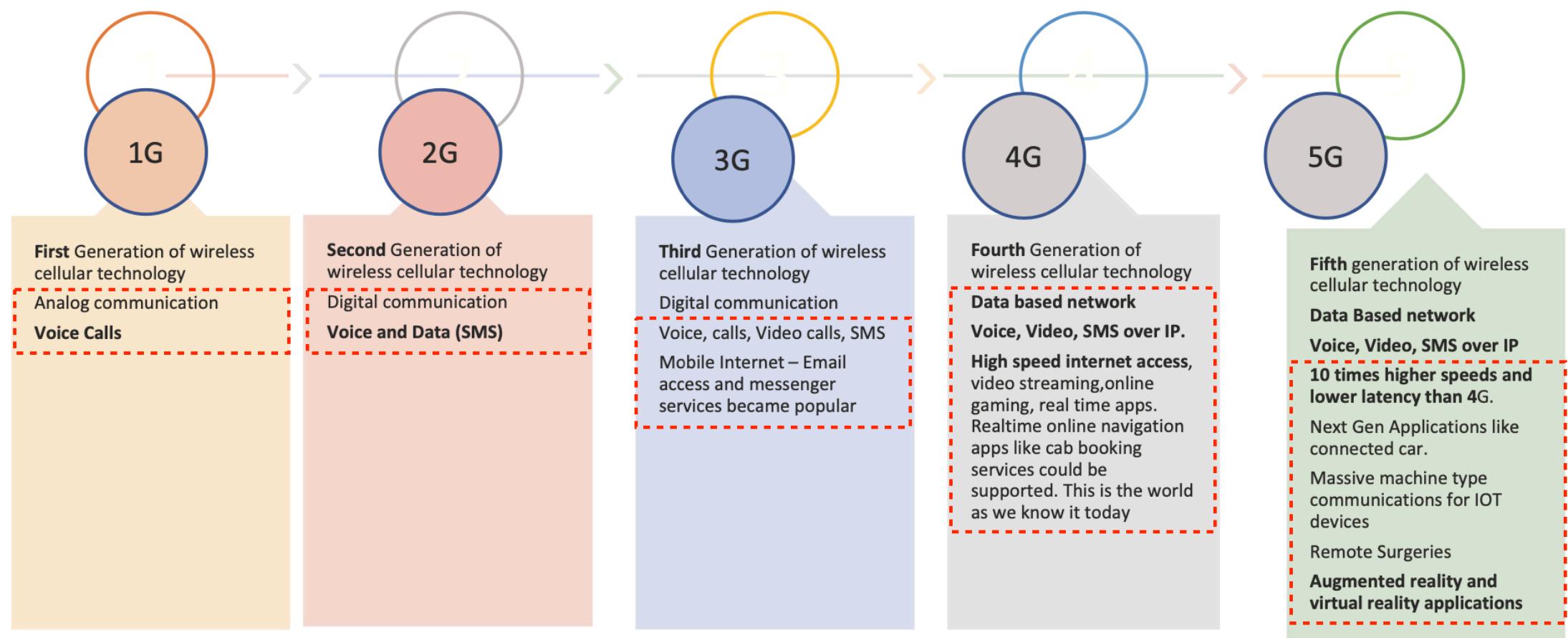
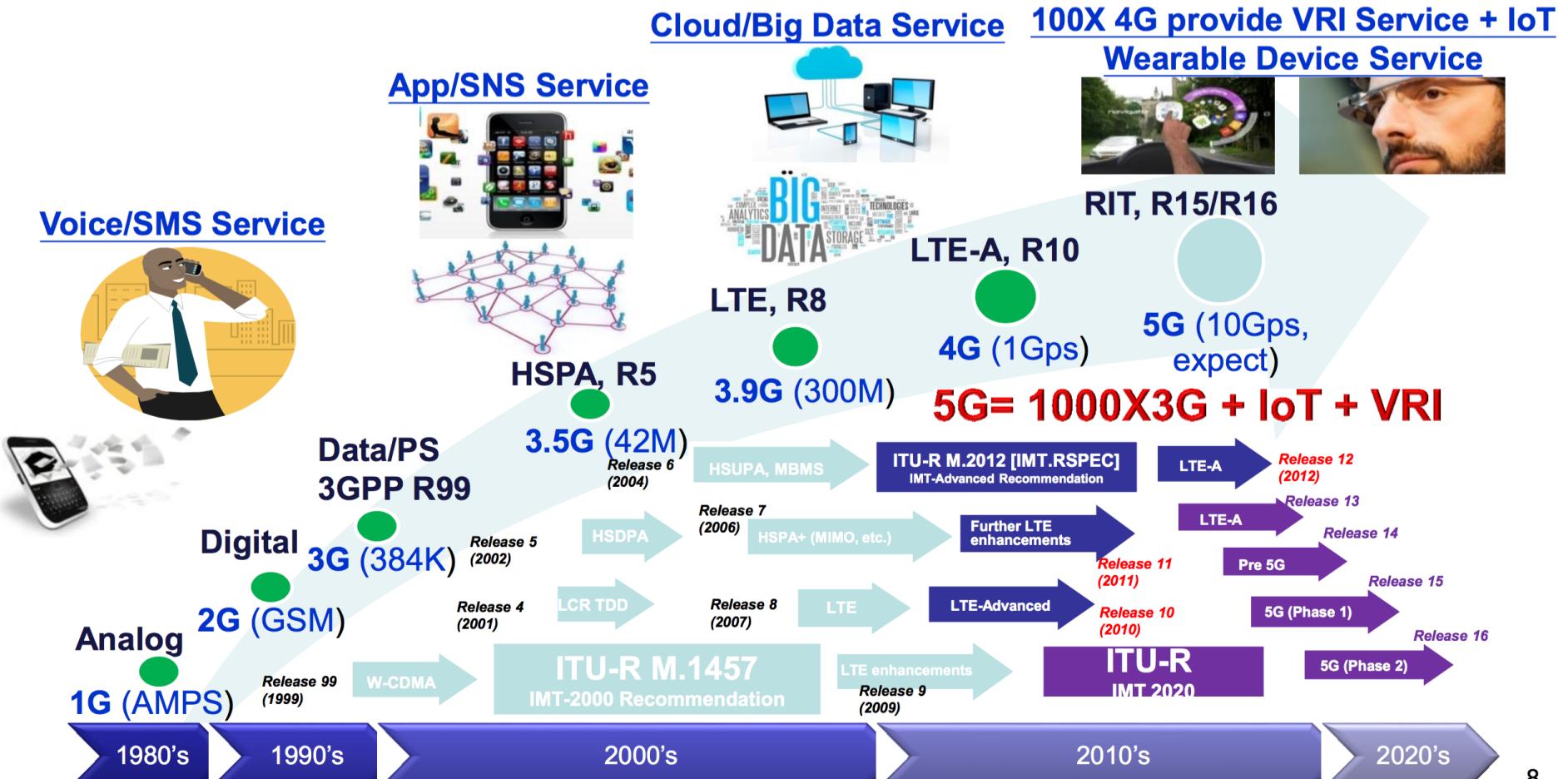


Overview of 5G and 6G Networks

Evolution of Mobile Communication



Evolution from 1G to 5G : Tech & Service



Innovation, Compassion, Effectiveness

VRI : Virtual Reality Imaging

3GPP Structure



Project Coordination Group (PCG) and Organizational Partners (OP)

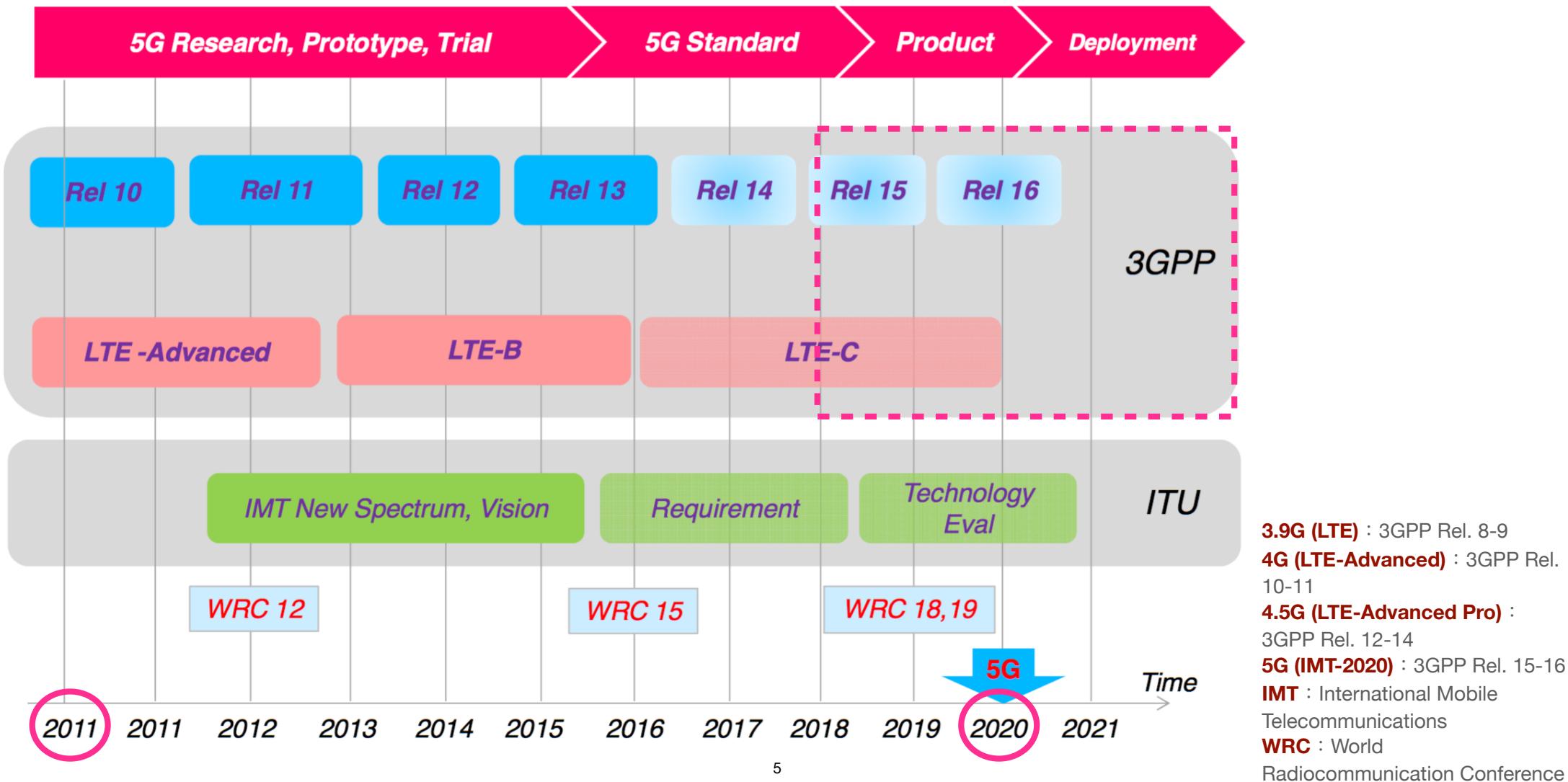
TSG SA Service and System Aspects
WG SA 1 Service Requirements
WG SA 2 System Architecture
WG SA 3 Security
WG SA 4 Codecs and Media Handling
WG SA 5 Telecom Management
WG SA 6 APIs and Vertical Applications

TSG CT Core Network and Terminals
WG CT 1 Radio Application Protocols
WG CT 3 External Inteworking
WG CT 4 Core Network Protocols
WG CT 6 Smart Card Application

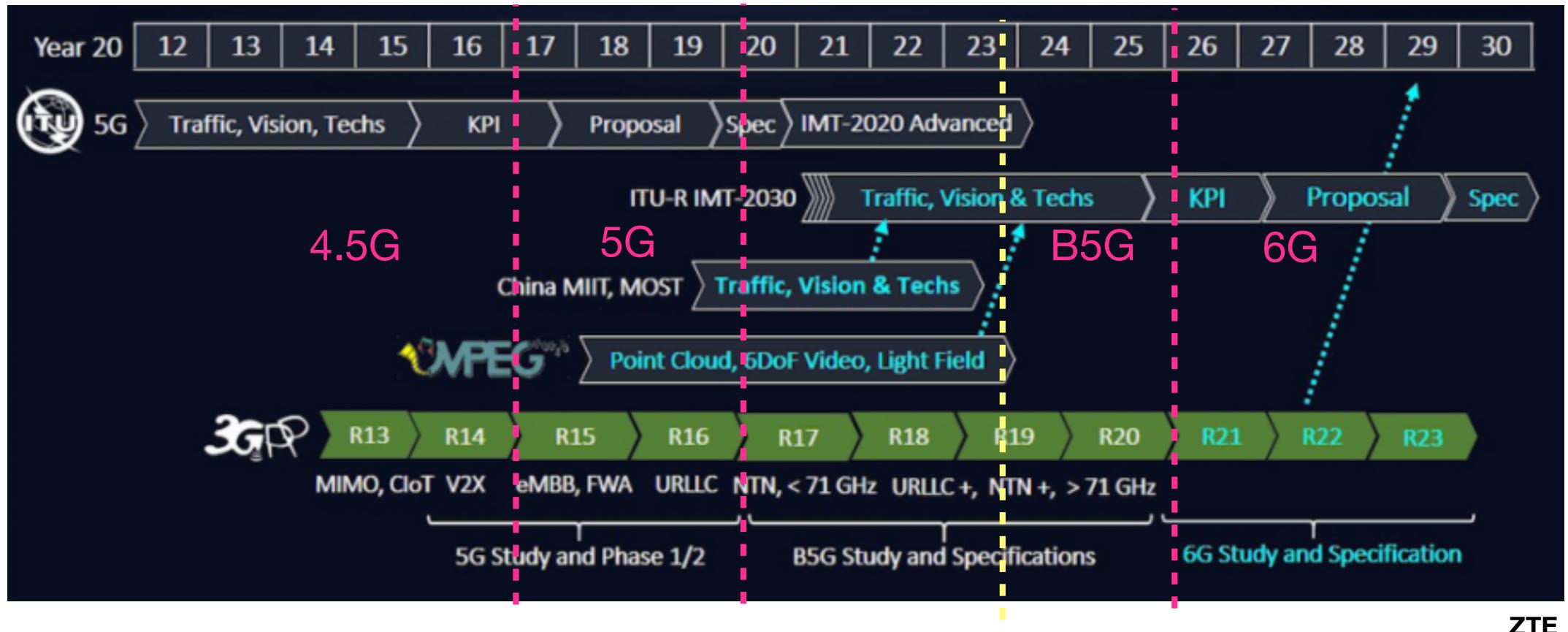
TSG RAN Radio Access Network
WG RAN 1 Radio Layer 1
WG RAN 2 Radio Layer 2 and 3
WG RAN 3 Radio Network Interfaces
WG RAN 4 Radio Performance Aspects
WG RAN 5 Mobile Conformance Testing

TSG = Technical Specification Group
WG = Working Group

3GPP Standardization Timeline (R10-R16)



3GPP Standardization Timeline (R13-R23)



4.5G (LTE-Advanced Pro) : 3GPP Rel. 12-14 5G (IMT-2020) : 3GPP Rel. 15-16 B5G : 3GPP Rel. 17-20 6G : 3GPP Rel. 21-23

3GPP

R15-17



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3GPP
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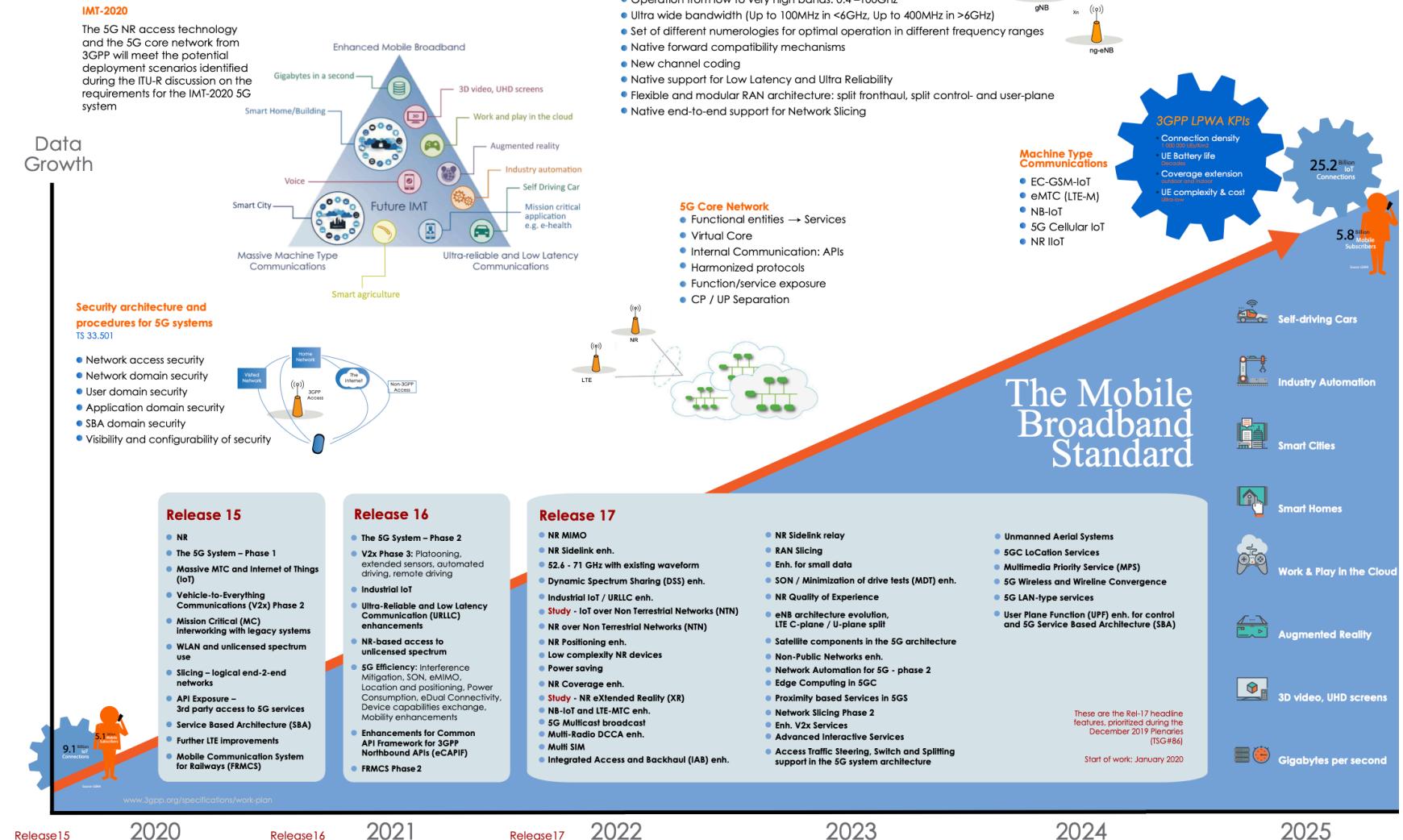


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Evolution across three major Releases



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3GPP

R18



Release 18



TSG SA priorities*

SA2 led - System Architecture and Services

- XR (Extended Reality) & media services
- Edge Computing Phase 2
- System Support for AI/ML-based Services
- Enablers for Network Automation for 5G Phase 3
- Enh. support of Non-Public Networks Phase 2
- Network Slicing Phase 3
- 5GC LoCation Services Phase 3
- 5G multicast-broadcast services Phase 2
- Satellite access Phase 2
- 5G System with Satellite Backhaul
- 5G Timing Resiliency and TSC & URLLC enh.
- Evolution of IMS multimedia telephony service
- Personal IoT Networks
- Vehicle Mounted Relays

- Access Traffic Steering, Switching & Splitting support in the 5G system architecture Phase 3
- Proximity-based Services in 5GS Phase 2
- UPF enh. for Exposure & SBA
- Ranging based services & sidelink positioning
- Generic group management, exposure & communication enh.
- 5G UE Policy Phase 2
- UAS, UAV & UAM Phase 2
- 5G AM Policy Phase 2
- RedCap Phase 2
- Support for 5WWC Phase 2
- System Enabler for Service Function Chaining
- Extensions to TSC Framework to support DetNet
- Seamless UE context recovery
- MPS when access to EPC/5GC is WLAN

SA3 led - Security and Privacy

- Privacy of identifiers over radio access
- SECAM and SCAS for 3GPP virtualized network products and Management Function (MnF)
- Mission critical security enhancements Phase 3
- Security and privacy aspects of RAN & SA features

SA4 led - Multimedia Codecs, Systems and Services

- Systems & Media Architecture:**
- 5G Media, Service Enablers
 - Split-Rendering
 - 5G AR Experiences Architecture
- Media:**
- Video codec for 5G
 - Media Capabilities for Augmented Reality Glasses
 - AI / ML Study
- Real-Time Communications:**
- XR conversational services
 - WebRTC-based services and collaboration models
- Immersive Voice & Audio:**
- EVS Codec Extension for Immersive Voice and Audio Services (IVAS_Codec)
 - Terminal Audio quality performance and Test methods for Immersive Audio Services (ATIAS)
- Streaming & Broadcast services:**
- 5GMS Enh. (Network slicing, Low latency, Background traffic, 5GMS Uplink)
 - Further MBS Enh. (Free to air, Hybrid unicast/broadcast)

*These are preliminary lists (As at SA#94-e)

© 3GPP, Dec. 2021

SA5 led - Management, Orchestration and Charging

Operations, Administration, Maintenance and Provisioning (OAM&P):

- Intelligence and Automation: Self-Configuration of RAN NEs, Enh. autonomous network levels, Evaluation of autonomous network levels, Enh. intent driven management services for mobile networks, AI / ML management, Enh. of the management aspects related to NWDAF

Management Architecture and Mechanisms: Network slicing provisioning rules, Enh. service based management architecture

- Support of New Services: Enh. Energy Efficiency for 5G Phase 2, New aspects of Energy Efficiency for 5G networks Phase 2, Enh. management of Non-Public Networks, Network and Service Operations for Energy Utilities, Key Quality Indicators(KQIs)for 5G service experience, Deterministic Communication Service Assurance

Charging:

- Charging Aspects for Enh. Support of Non-Public Networks

SA6 led - Application Enablement & Critical Communication Applications

Critical Communications:

- MCX Enhancements – MC over 5GS (5MBS, ProSe) Adhoc group comm., MCPIT Enh.
- Railways - Gateway UE, Interworking

Service Frameworks:

- Edge App Architecture Enh., SEAL Enh., Subscriber-Aware API (CAPIF Enh.)
- Fused location, Application Data Analytics, App Layer NW Slicing
- **Enablers for Vertical Applications:**
- Enhancements to V2X, UAS application-enablement
- Future Factories, Personal IoT networks, Capability exposure for IoT platforms

See the 3GPP Work Plan for full details, as Release 18 develops:
www.3gpp.org/specifications/work-plan

TSG RAN priorities*

RAN1 led - Radio Layer 1 (Physical layer)

- NR-MIMO Evolution
- AI/ML - Air Interface
- Evolution of duplex operation
- NR Sidelink Evolution
- Positioning Evolution
- RedCap Evolution
- Network energy savings
- Further UL coverage enhancement
- Smart Repeater
- DSS
- Low power WUS
- CA enhancements

RAN2 led - Radio layer 2 & layer 3 Radio Resource Control

- Mobility Enhancements
- Enhancements for XR
- Sidelink Relay Enhancements
- NTN (Non-Terrestrial Networks) evolution - NR
- NTN (Non-Terrestrial Networks) evolution - IoT
- UAV (Uncrewed Aerial Vehicle)
- Multiple SIM (MUSIM) Enhancements
- In-Device Co-existence (IDC) Enhancements
- Small data
- MBS

RAN3 led - UTRAN/E-UTRAN/NG-RAN architecture & related network interfaces

- Additional topological improvements – IAB/VMR
- AI/ML for NG-RAN WI
- AI/ML for NG-RAN SI
- SON/MDT Enhancements
- QoE Enhancements
- Resiliency of gNB-CU-CP

RAN4 led - Radio Performance and Protocol Aspects

- RAN4-led spectrum items
- <5MHz in dedicated spectrum

Rel-18 Workplan for TSG CT

CT will work on Stage 3 completion and ASN.1 code and OpenAPI freeze of Rel-17 until June 2022 (TSG#96).

Work item discussion on Rel-18 Stage 2 / Stage 3 (under CT) from June 2022.

*Source: RP-213697 (RAN#94-e)

- Release 15
 - NR
 - The 5G System - Phase 1
 - Massive MIC and Internet of Things (IoT)
 - Vehicle-to-Everything Communications (V2x) Phase 2
 - Mission Critical (MC) interworking with legacy systems
 - WLAN and unlicensed spectrum use
 - Slicing - logical end-2-end networks
 - API Exposure - 3rd party access to 5G services
 - Service Based Architecture (SBA)
 - Further LTE improvements
 - Mobile Communication System for Railways (FRMCS)

• Release 16

- The 5G System - Phase 2
- V2x Phase 3: Platooning, extended sensors, automated driving, remote driving
- Industrial IoT
- Ultra-Reliable and Low Latency Communication (URLLC) enhancements
- NR-based access to unlicensed spectrum
- 5G Efficiency: Interference Mitigation, SON, eMIMO, Location and positioning, Power Consumption, eDual Connectivity. Device capabilities exchange. Mobility enhancements
- Enhancements for Common API Framework for 3GPP Northbound APIs (eCAPIF)
- FRMCS Phase2

- Release 17
 - NR MIMO
 - NR sidelink enh.
 - 52.6 - 71 GHz with existing waveform
 - Dynamic Spectrum Sharing (DSS) enh.
 - Industrial IoT / URLLC enh.
 - Study- IoT over Non Terrestrial Networks (NTN)
 - NR over Non Terrestrial Networks (NTN)
 - NR positioning enh.
 - Low complexity NR devices
 - Power saving
 - NR coverage enh.

- Study - NR eXtended Reality (XR)
- NB-IoT and LTE-MTC enh.
- 5G multicast broadcast
- Multi-Radio DCCA enh.
- Multi SIM
- Integrated Access and Backhaul (IAB) enh.
- NR sidelink relay
- RAN slicing
- Enh. for small data
- SON / Minimization of Drive Tests (MDT) enh.
- NR Quality of Experience

- eNB architecture evolution, LTE C-plane / U-plane split
- Satellite components in the 5G architecture
- Non-Public Networks enh.
- Network automation for 5G - phase 2
- Edge computing in 5GC
- Proximity based services in 5GS
- Network slicing phase 2
- Enh. V2x services
- Advanced interactive services

- Access traffic steering, switch and splitting support in the 5G system architecture Unmanned Aerial Systems (UAS)
- 5GC LoCation Services (LCS)
- Multimedia Priority Service (MPS)
- 5G Wireless and Wireline Convergence
- 5G LAN-type services
- User Plane Function (UPF) enh. for control and 5G Service Based Architecture (SBA)

- Release 18

- **Extension**

- Uplink coverage
- IoT optimized RedCap
- Non-terrestrial networks (NTN)
- UAV optimization
- Sidelink enhancements
- Sub 5MHz for verticals

- **Expansion**

- Positioning
- Resilient timing

- **Experience**

- Extended reality (XR)
- MIMO enhancements
- Mobility enhancements
- Duplex operations

- **Excellence**

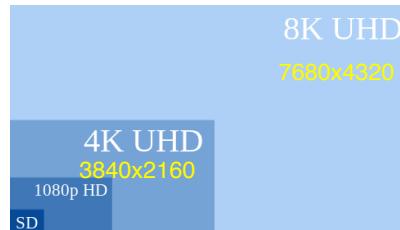
- AI/ML for NG-RAN
- AI/ML for Air Interface
- Network energy efficiency
- Centralized unit resiliency
- Network-controlled repeater
- DSS enhancements
- Mobile IAB

QoS Requirements: 4G & 5G

Parameters	4G	5G
Air Link User Plane Latency	10 ms	1 ms
Air Link Control Plane Latency	100 ms	50 ms
Simultaneous Connection Density per km ²	10^5	10^6
Mobility	300 km/h	500 km/h
Uplink Cell Spectral Efficiency	1.8 bps/Hz	5 bps/Hz
Downlink Cell Spectral Efficiency	2.6 bps/Hz	10 bps/Hz
Peak Throughput (Downlink) per Connection	100 Mbps to 1 Gbps	10 Gbps to 50 Gbps
Cell Edge Data Rate	1 Mbps	1 Gbps
Cost Efficiency	10 times	100 times
Packet Delay Budget without Quality Assurance	100 to 300 ms	Undetermined
Packet Delay Budget with Guaranteed Quality	50 to 300 ms	1 ms
Packet Loss Ratio for video broadcasting	10^{-8} (4k UHD)	10^{-9} (8k UHD)
Packet Loss Ratio for M2M Services (without quality assurance)	10^{-3}	10^{-4}
Packet Loss Ratio for M2M Services (without guaranteed quality)	10^{-6}	10^{-7}

ITU 5G Service Scenarios

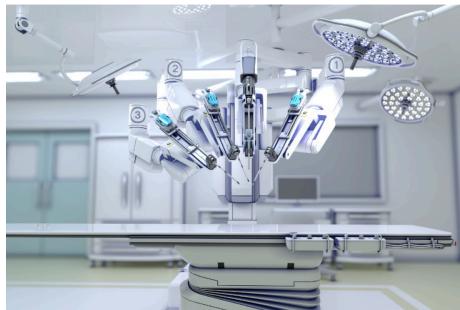
- Enhanced Mobile Broadband (eMBB)
- Downlink higher data rate (gigabyte/sec) services
 - Ultra-high definition (UHD) video
 - 3D video
 - Augmented Reality (AR) / Virtual Reality (VR)
- Uplink high data rate service
 - HD video sharing from the users

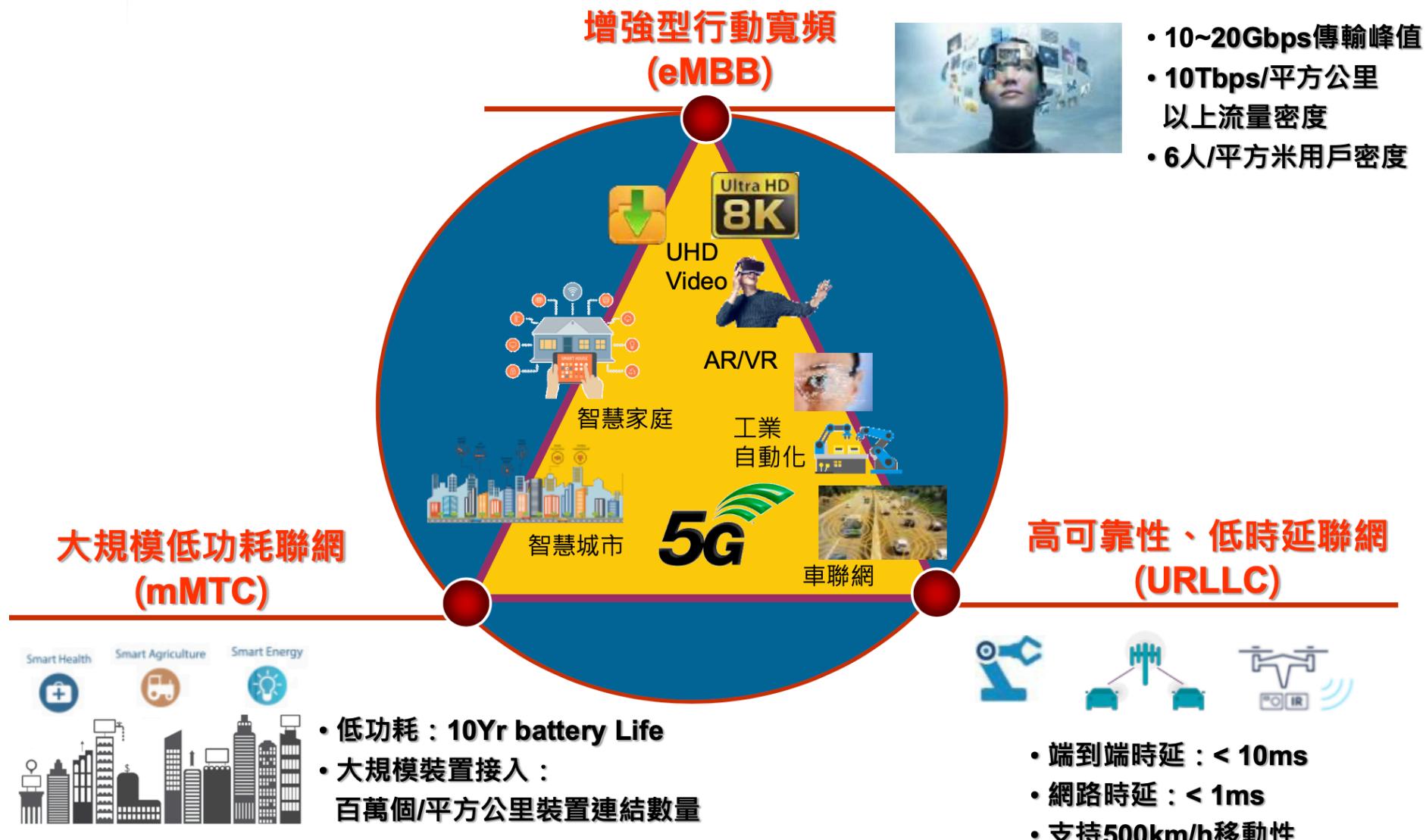


- **Massive Machine Type Communications (mMTC)**
- Services that use massive number of sensors to report the sensing data to the cloud or a central data center to
 - Smart city
 - Smart homes / buildings
 - Remote sensors

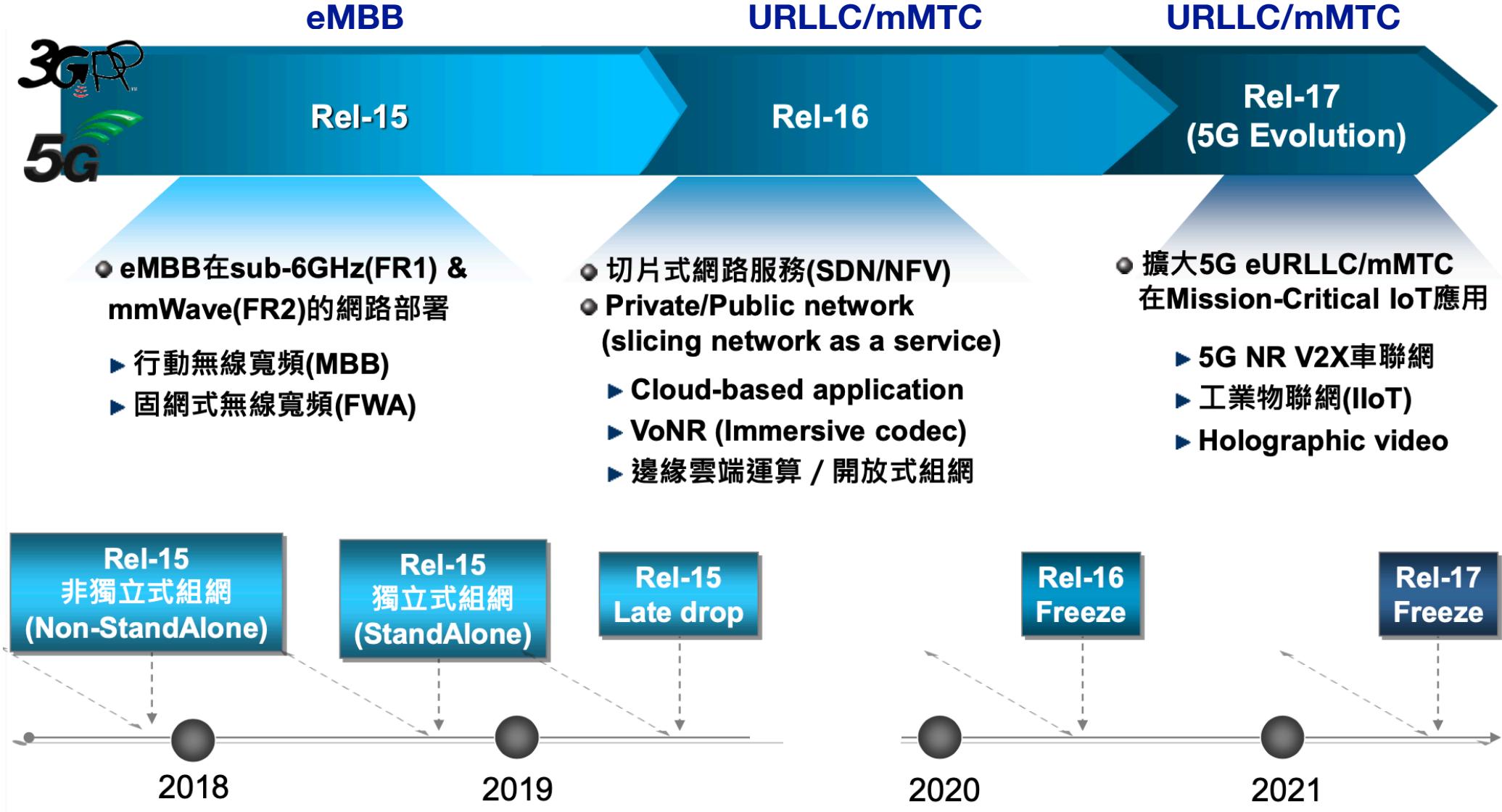


- **Ultra-Reliable and Low Latency Communications (URLLC)**
- Services that are very sensitive to latency and loss of data packets
 - Industry automation
 - Self-driving car
 - Mission-critical application like remote surgery
 - Augmented Reality





資料來源：DIGITIMES · 2019/11

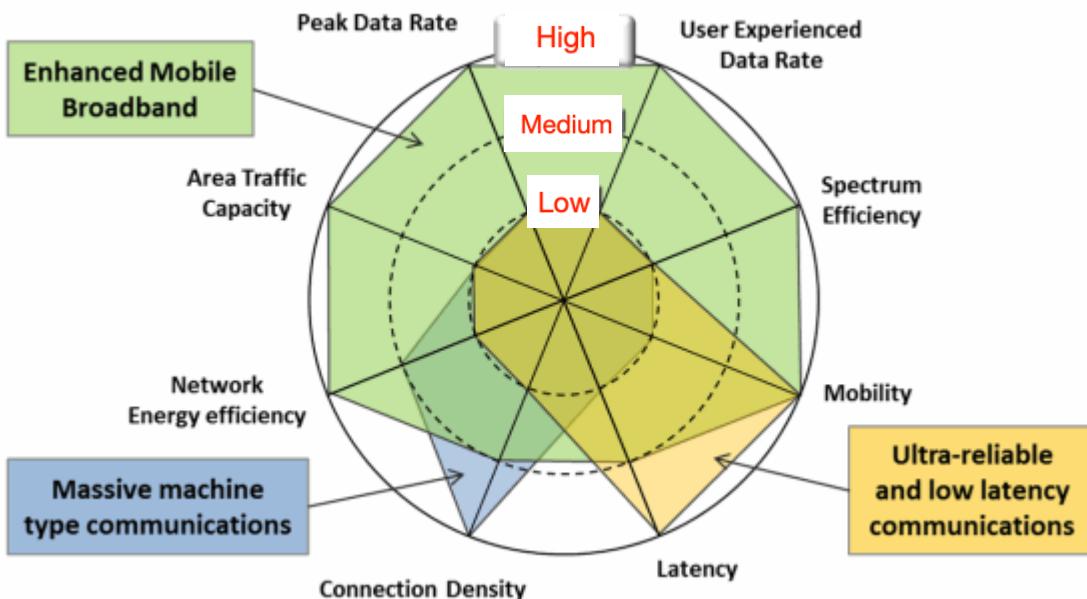


資料來源：DIGITIMES · 2019/11

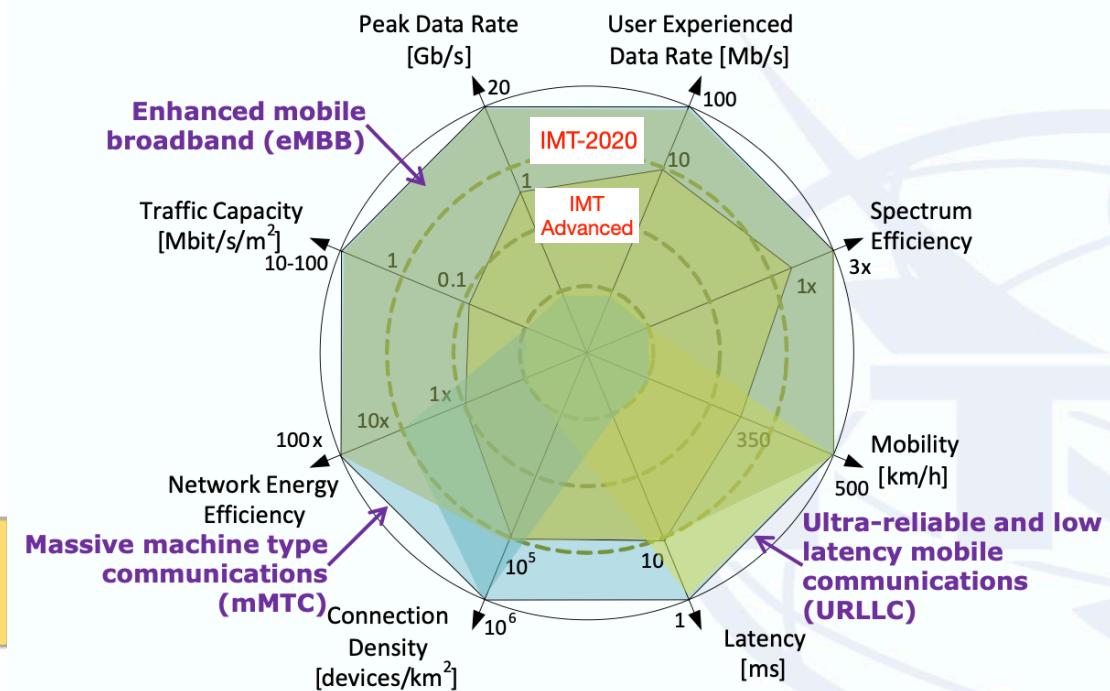
Key Capabilities for 5G

- User experienced data rate [Mb/s]
- Peak data rate [Gb/s]
- Mobility [km/h]
- Latency [ms]
- Connection density [devices/km²]
- Energy efficiency
- Spectrum efficiency
- Area traffic capacity [Mb/s/m²]

IMT-2020



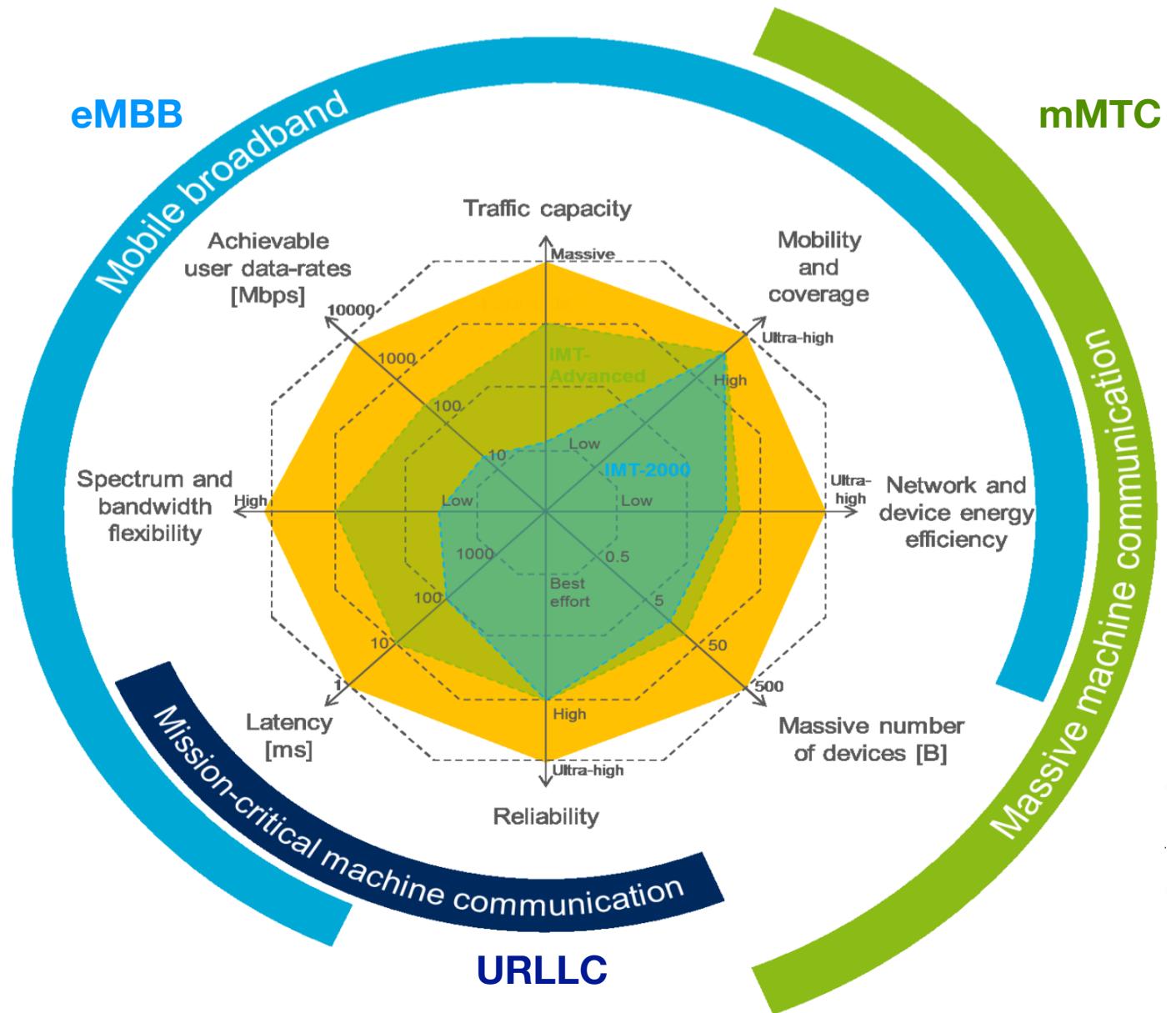
The importance of key capabilities in different usage scenarios



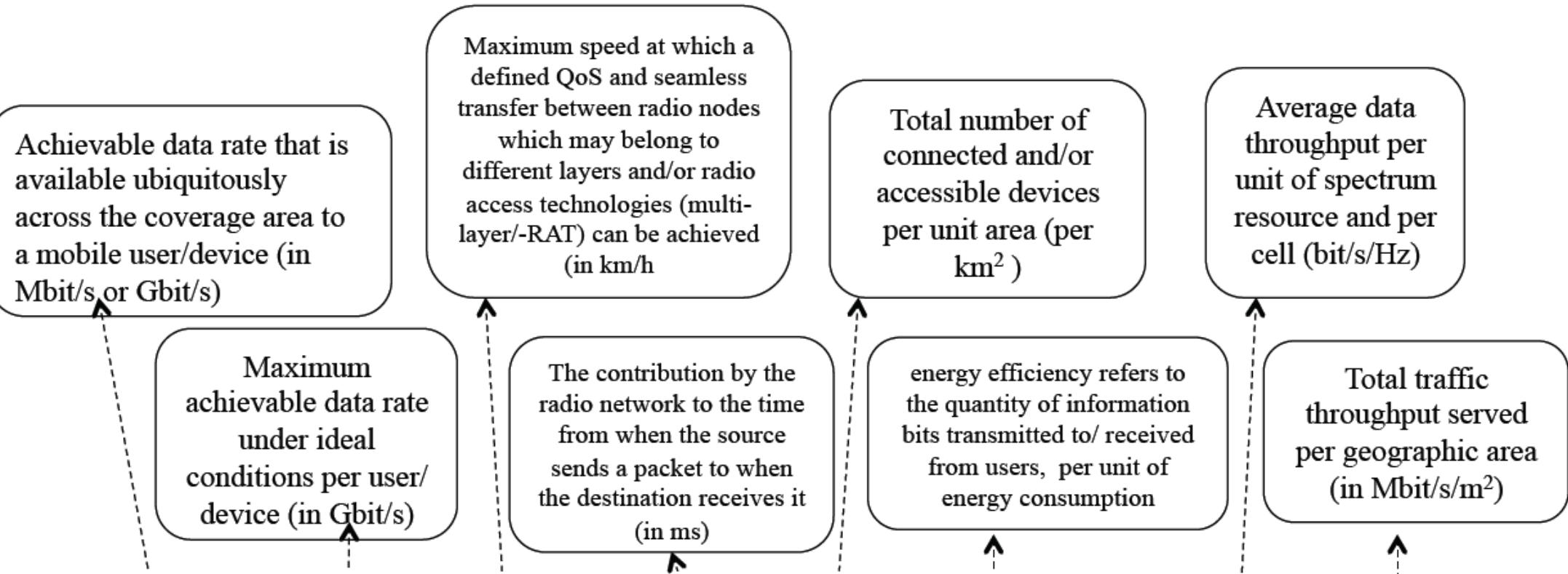
Enhancement of key capability for 5G

IMT-2020 (5G) key capabilities

- Traffic capability
- Mobility and coverage
- Network and device energy efficiency
- Massive number of devices
- Reliability
- Latency
- Spectrum and bandwidth flexibility
- Achievable user data rates



	eMBB	mMTC	URLLC
Data Rate	Very high (e.g. peak rate 10 Gbps)	Not much considered	Not much considered
Latency	Low	Not much considered	Very Low (e.g. 0.5 ms end-to-end)
Mobility	0km/h to 500km/h	Not much considered	Not much considered
Reliability	Not much considered	Not much considered	Very High (e.g. Packet loss rate: as low as 1e-04)
Power Consumption	Not much considered	Very Low	Not much considered
Connection Density	High (e.g. 200-2500 UEs/km ²)	Very High (e.g. 1M connections/ km ²)	High (e.g. 10k device/10km ²)

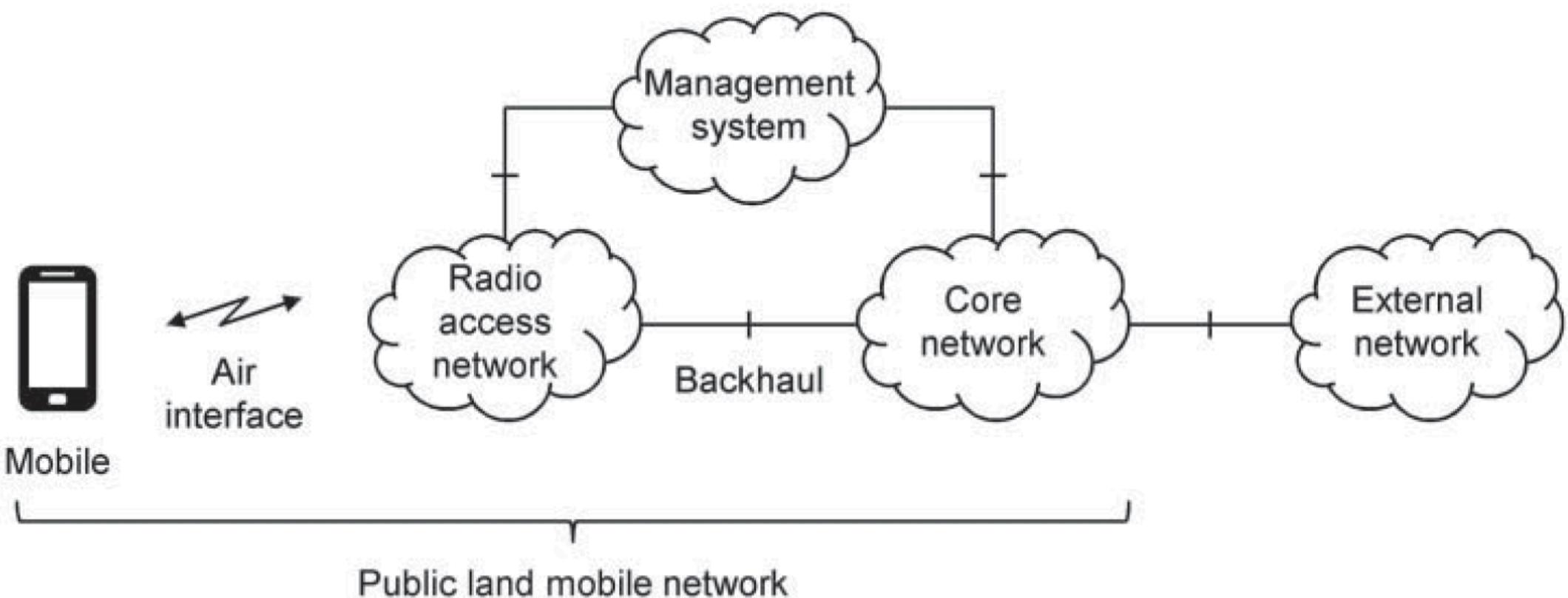


Parameter	User experienced data rate	Peak data rate	Mobility	Latency	Connection density	Energy efficiency	Spectrum efficiency	Area traffic capacity (ultra-dense network)
Value for future IMT	100Mbit/s	20 Gbit/s	500km/h	1ms (radio interface)	10^6 Devices/ km^2	100 times IMT-Advanced (for network)	3 times IMT-Advanced	10Mbits/s/ m^2

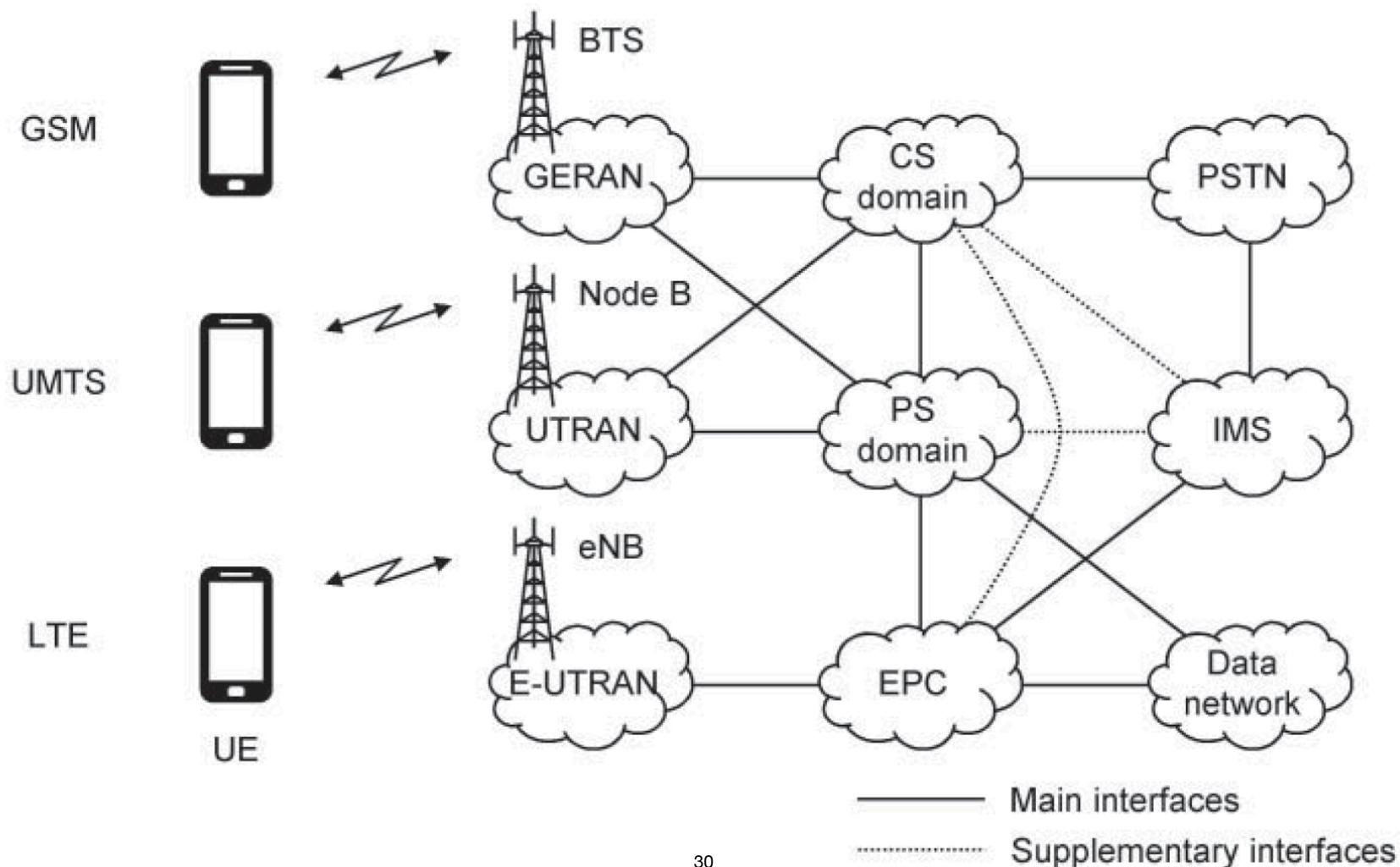
1 ms : air latency. 5-10 ms : E2E latency

應用情境	技術指標	技術目標數值
eMBB	Peak data rate	20 Gbps for downlink 10 Gbps for uplink
	Peak spectral efficiency	30 bps/Hz for downlink 15 bps/Hz for uplink
	C-plane latency	10 ms
	U-plane latency	4 ms for downlink 4 ms for uplink
	Cell/TRxP spectral efficiency	3 times higher than IMT-A
	Area traffic capacity	3 times higher than IMT-A
	User experienced data rate	3 times higher than IMT-A
	5% user spectrum efficiency	3 times higher than IMT-A
uRLLC	U-plane latency	0.5 ms for downlink 0.5 ms for uplink
	Reliability	10^{-5} for 32 bytes with U-plane latency of 1 ms
mMTC	Coverage	Max coupling loss 164 db
	UE battery life	Beyond 10 years
	Connection density	1000000 devices/km ²

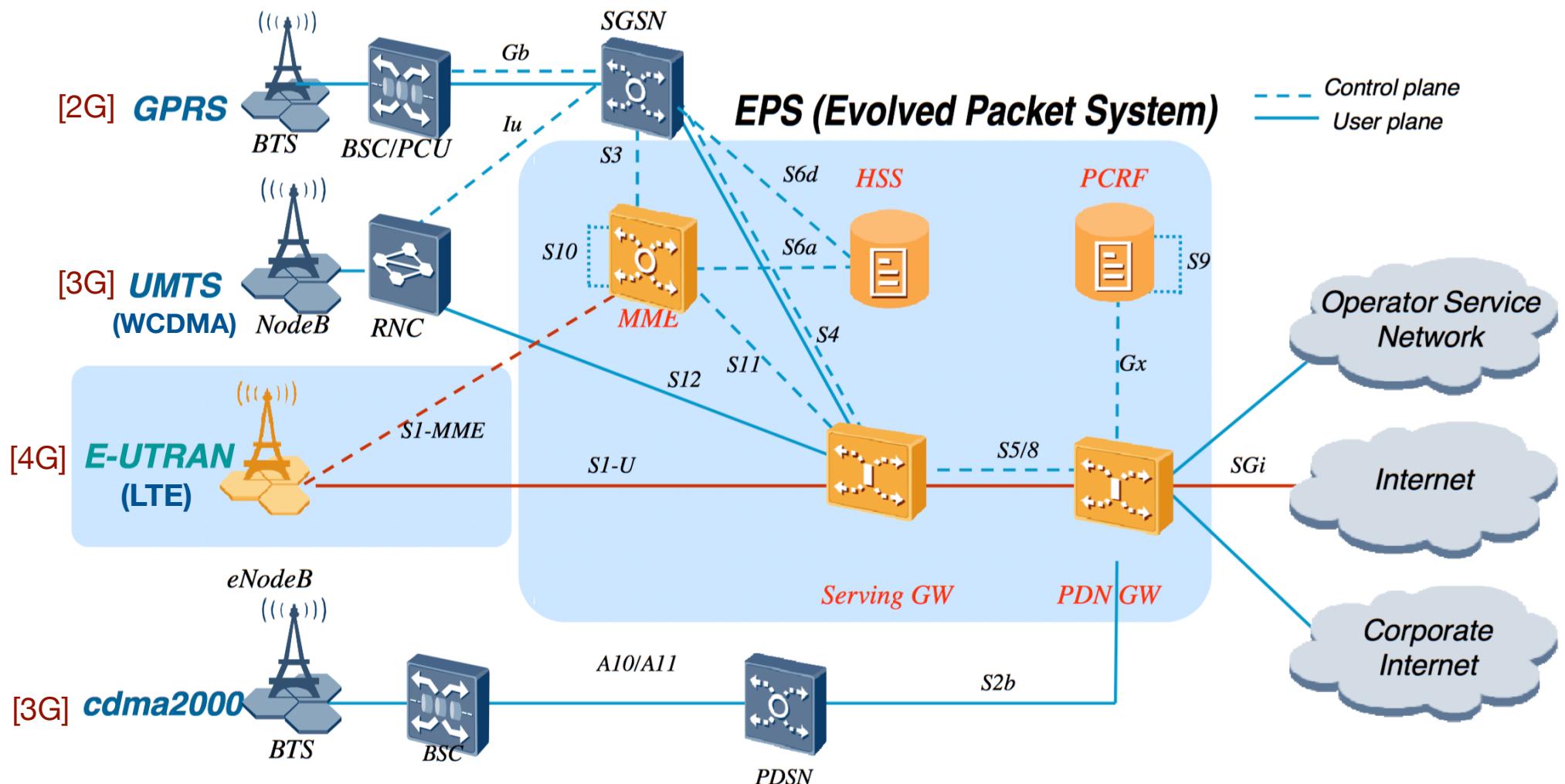
Architecture of Mobile Telecommunication System



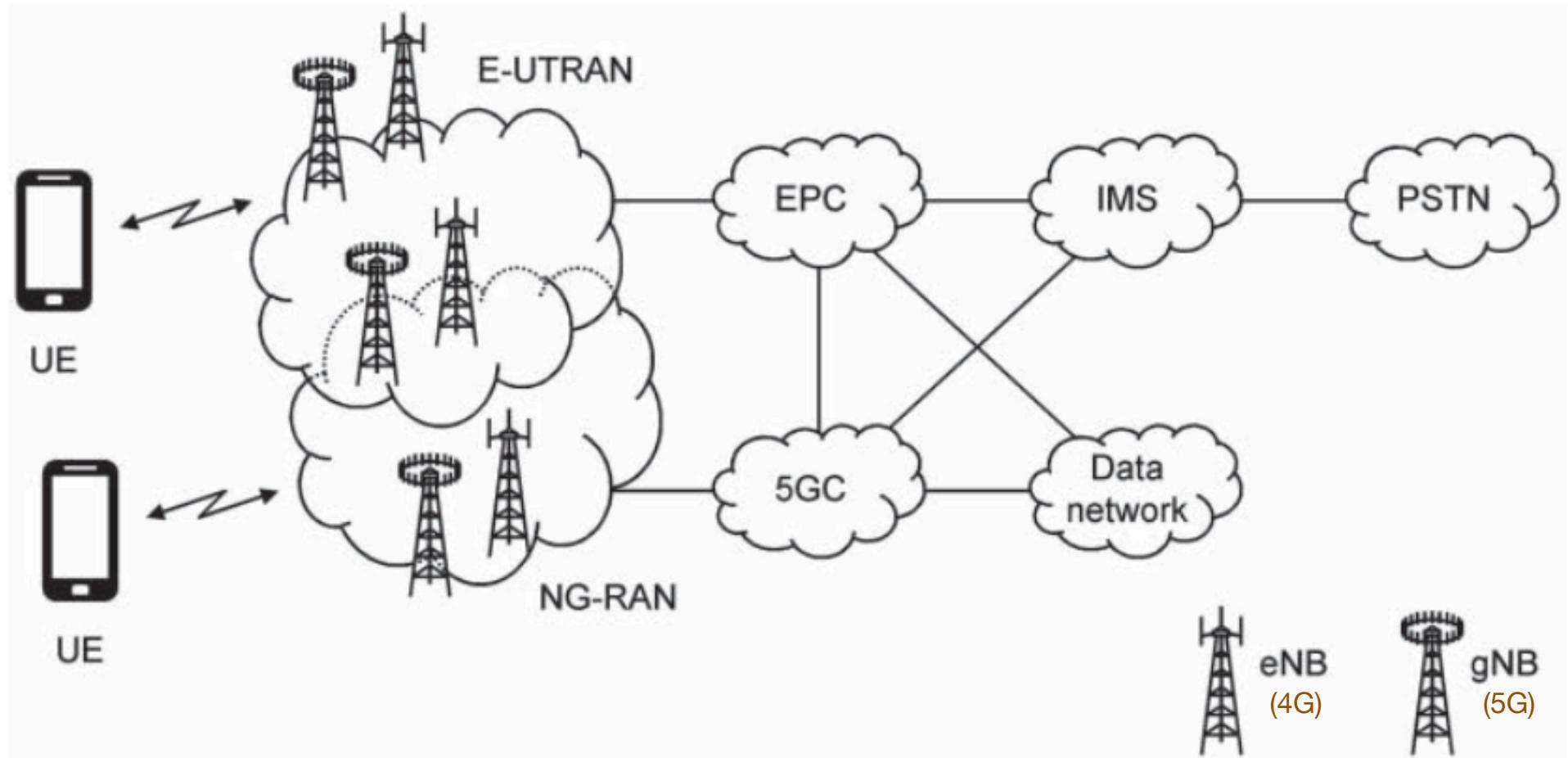
Architecture of GSM, UMTS and LTE



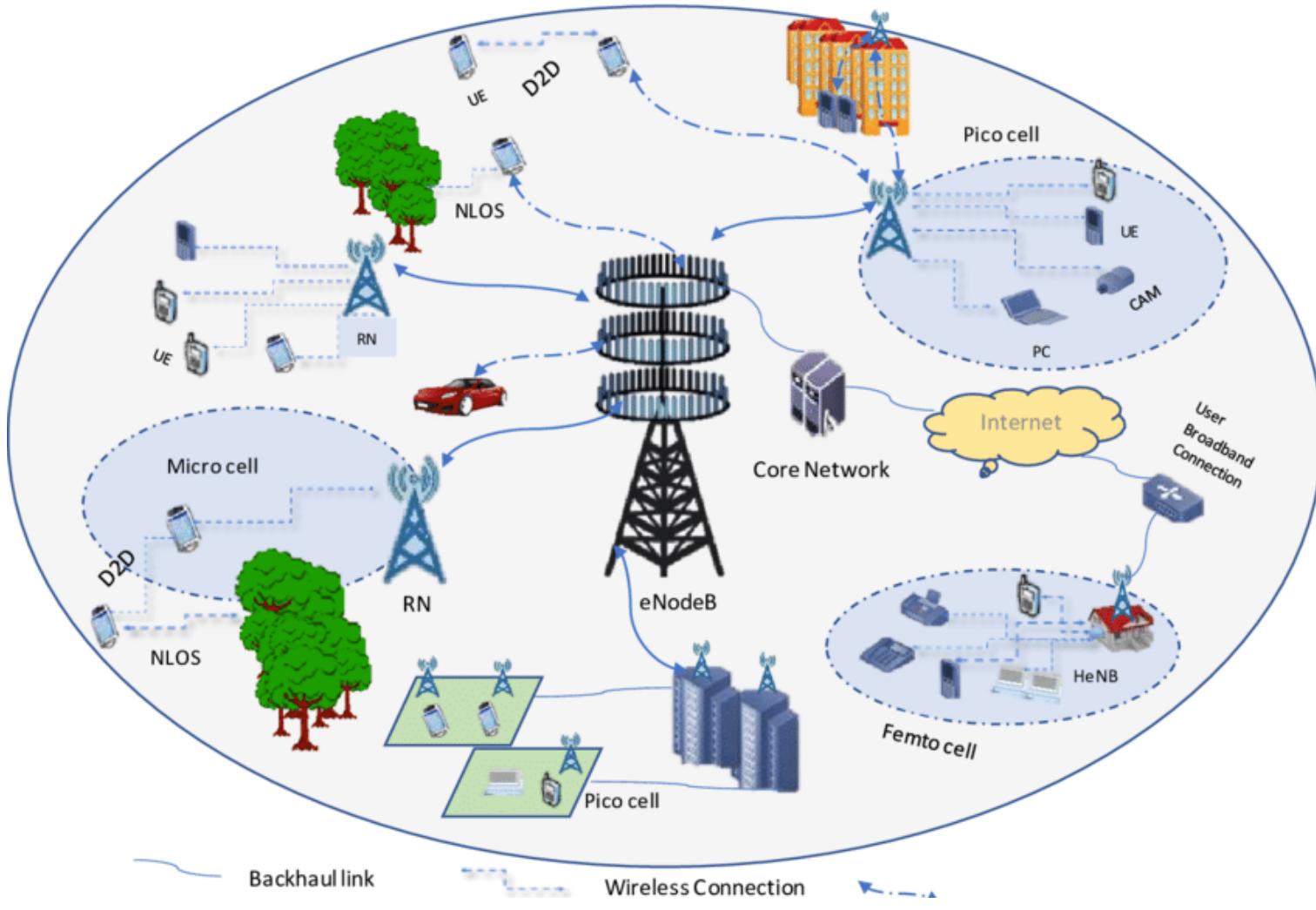
GSM/UMTS/LTE Network Architecture



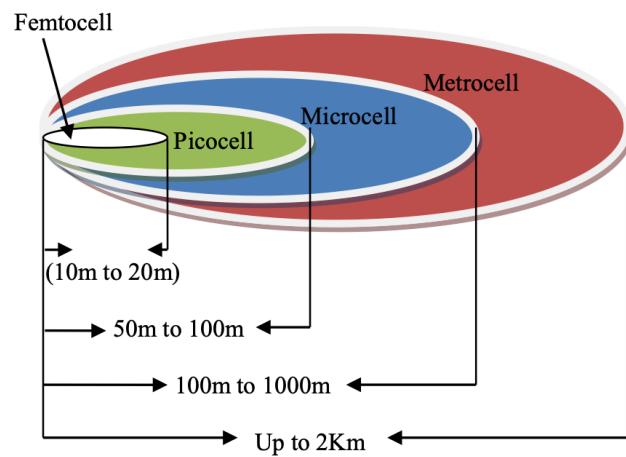
High-level Architecture of 5G



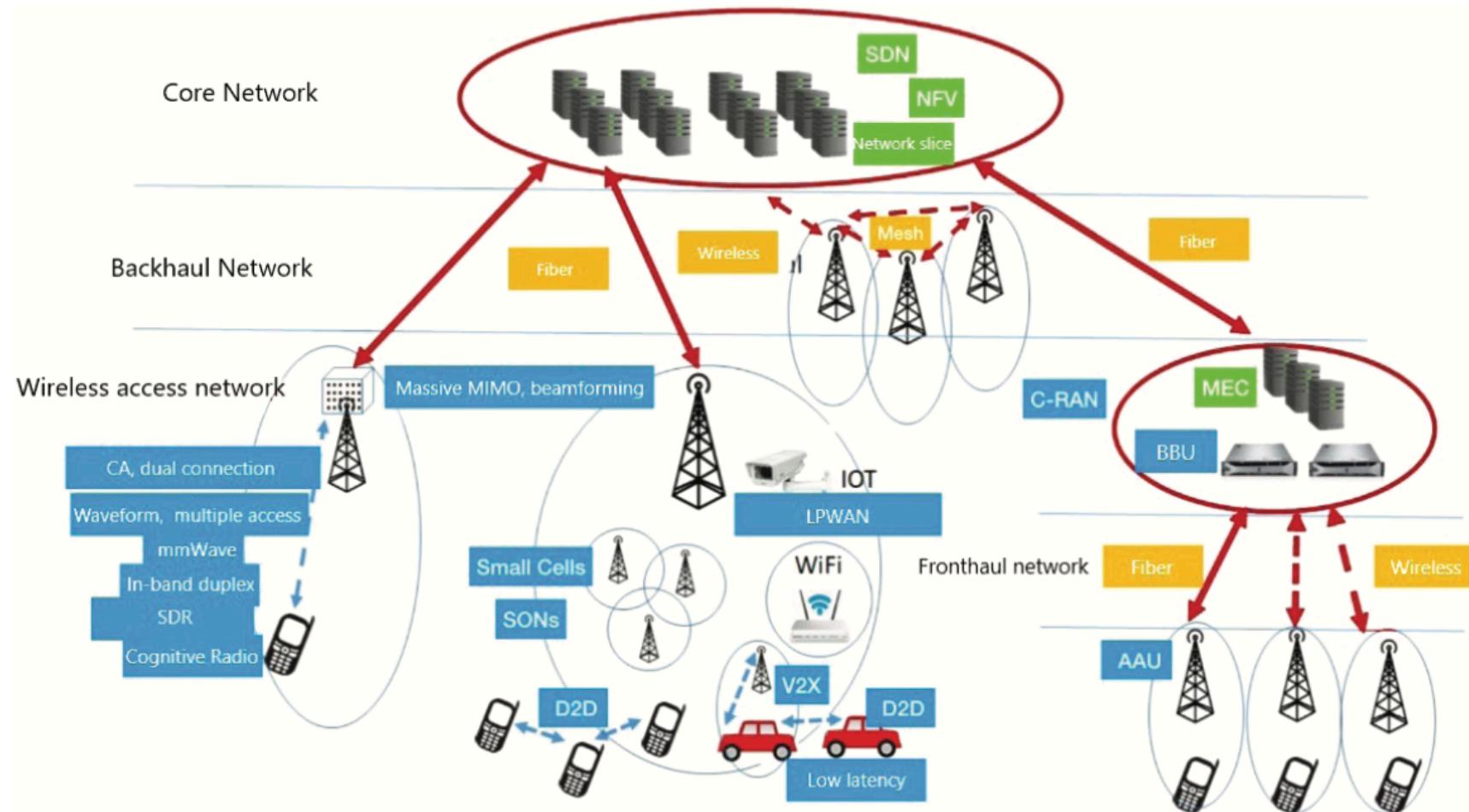
5G Heterogeneous Networks (HetNets)



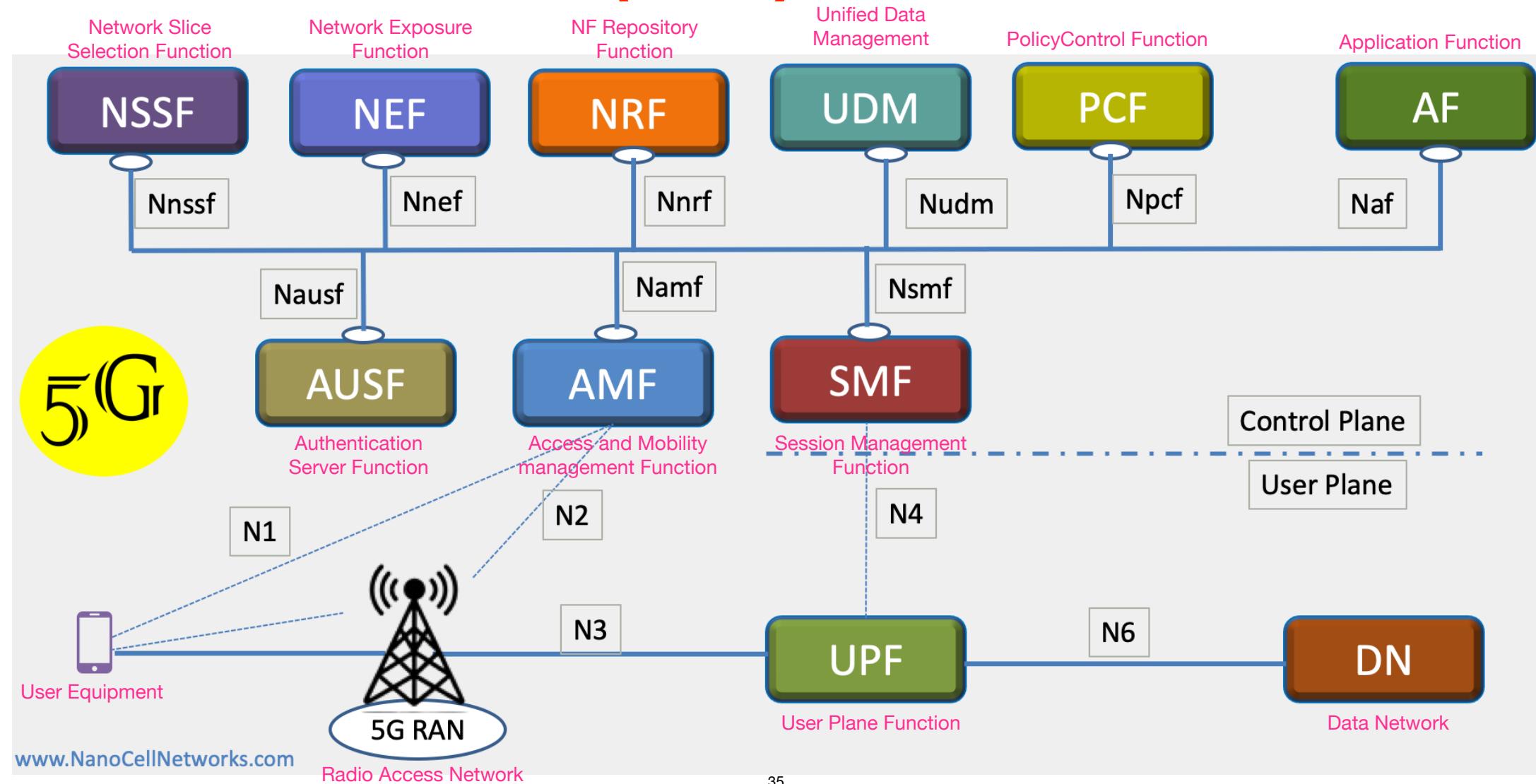
33



Overall Architecture of 5G Network (Core Network, Backhaul / Fronthaul Network, RAN)



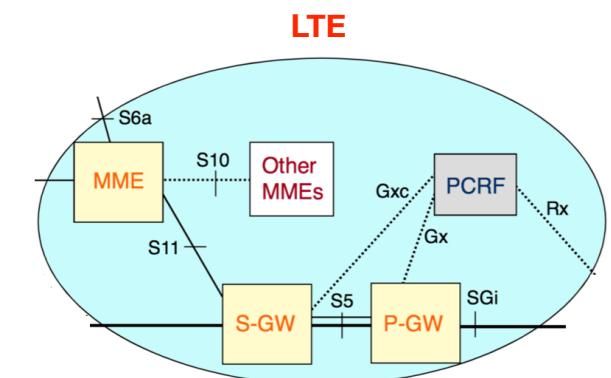
5G Core Network (SBA)



5G Core (5GC) Service-Based Architecture (SBA)

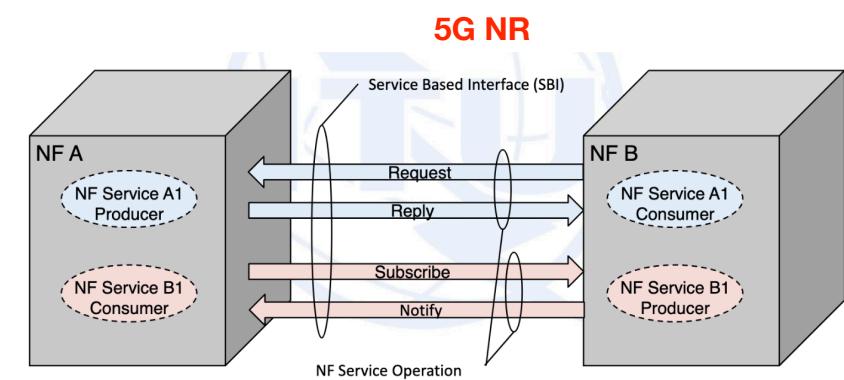
- EPC architecture

- The control plane functions communicate with each other via the direct interfaces (or reference points) with a standardized set of messages

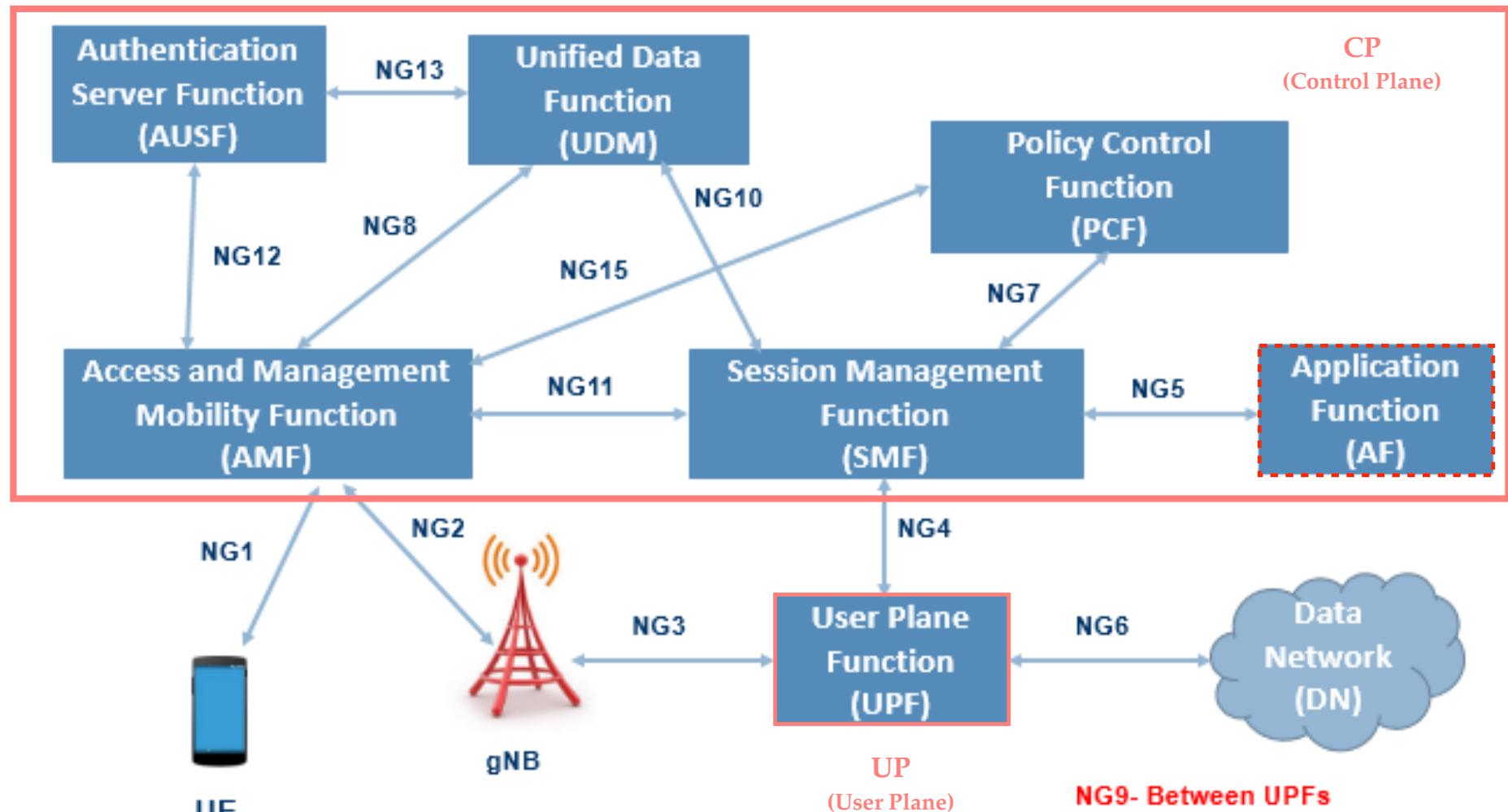


- SBA architecture

- The Network Functions (NF), using a common framework, expose their services for use by other network functions through Service-Based Interfaces (SBI)



Service-Based Architecture



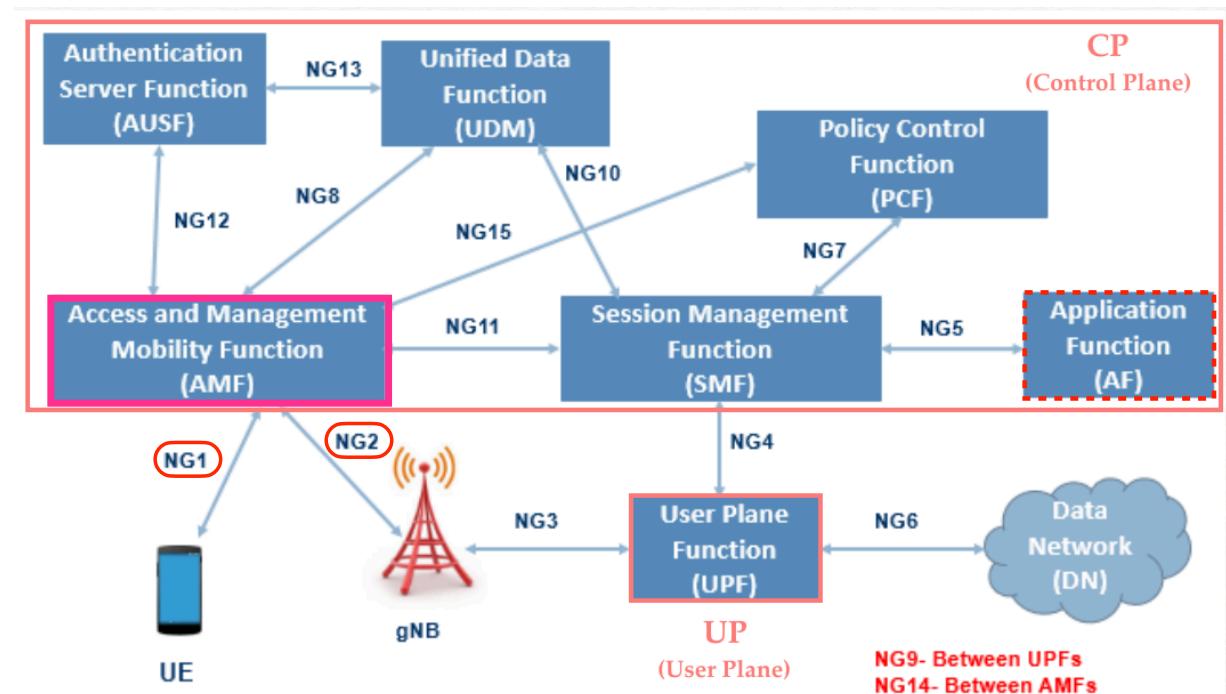
UE : User Equipment

gNB : Next Gen Node Basestation

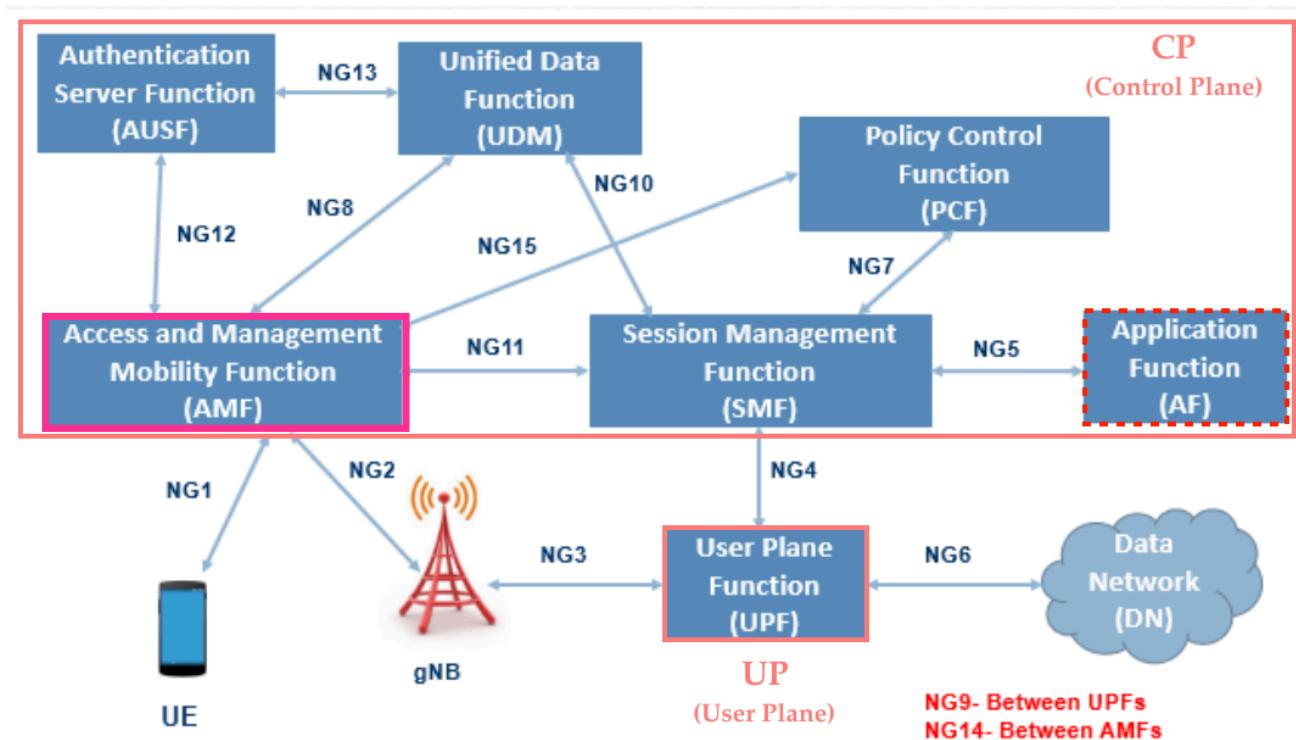
Source 3GPP TR 23.799

Network Nodes and Functions

- Access and Mobility Management Function (AMF)
 - Termination of RAN Control Plane interface (**NG2**)
 - Termination of NAS (**NG1**), NAS ciphering and integrity protection
 - Mobility management



- Lawful intercept for AMF events and interface to Lawful Intercept System
- Transparent proxy for routing access authentication and SM messages
- Access authentication
- Access authorization

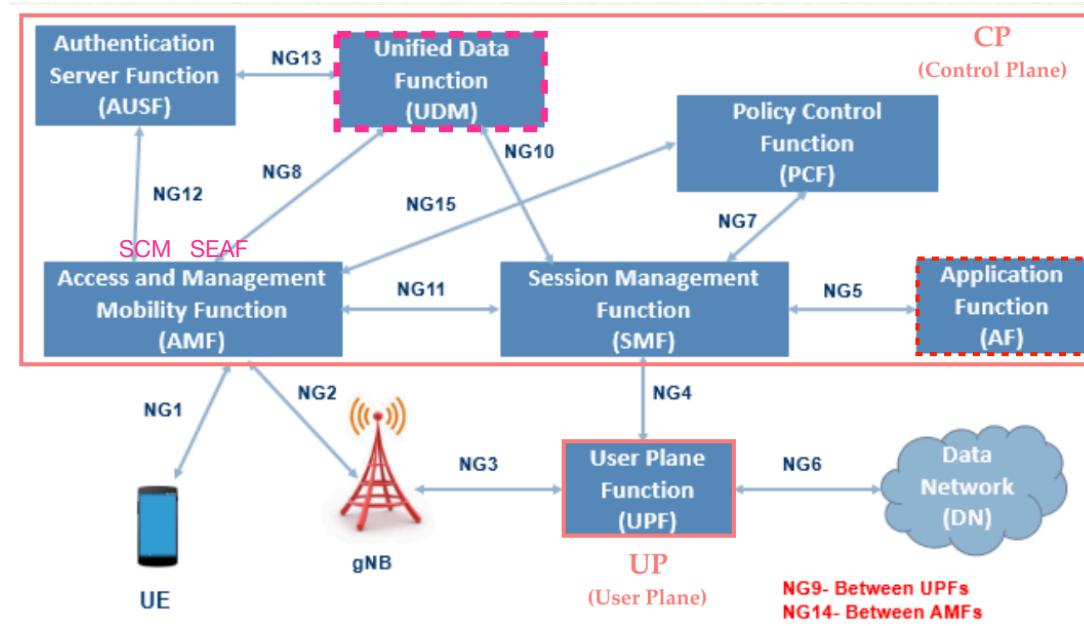


• Security Anchor Function (SEAF)

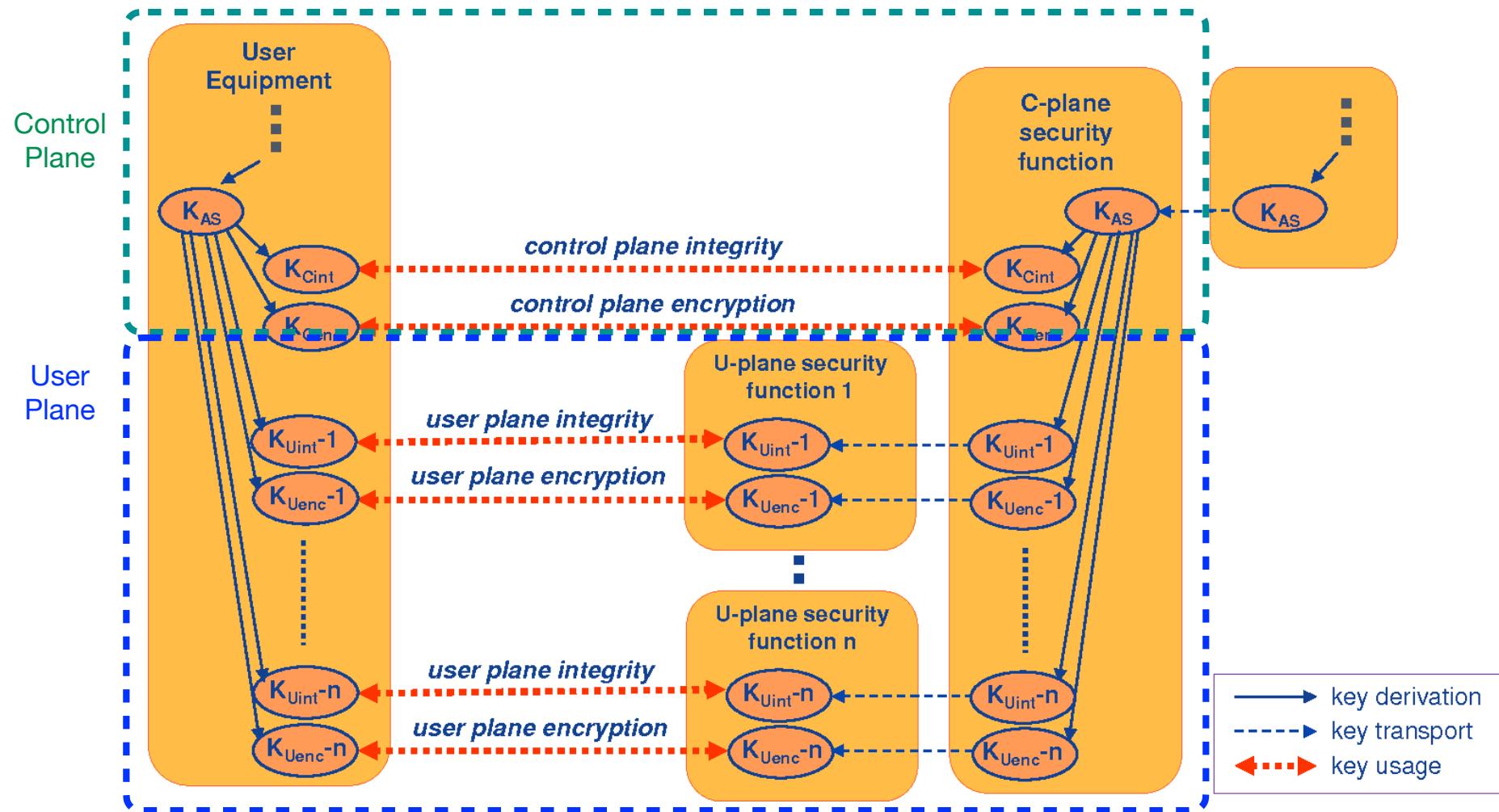
- Interact with UDM and UE, receives the intermediate key that was established as a result of UE authentication process
- In case of USIM based authentication, AMF retrieves the security material from UDM

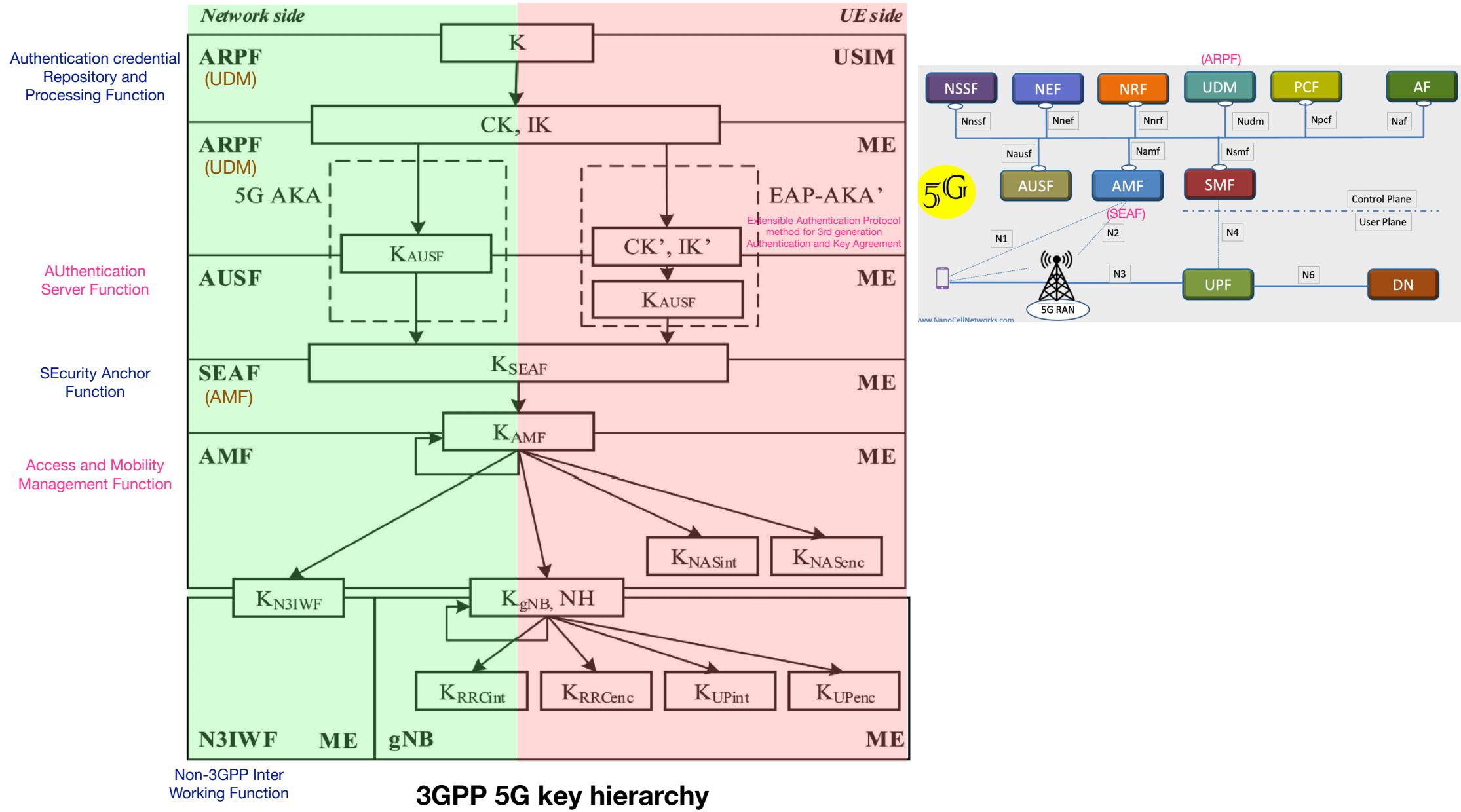
• Security Context Management (SCM)

- Receive a key from SEAF that it uses to derive access-network specific keys



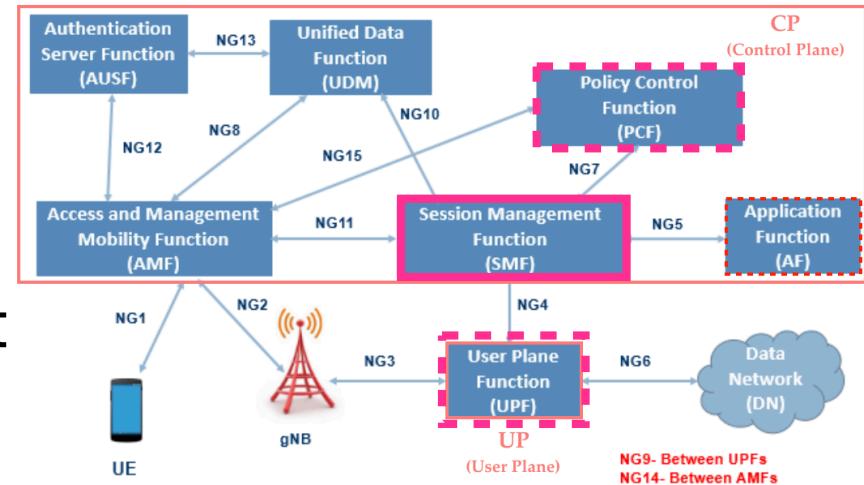
Access Stratum (AS) Security



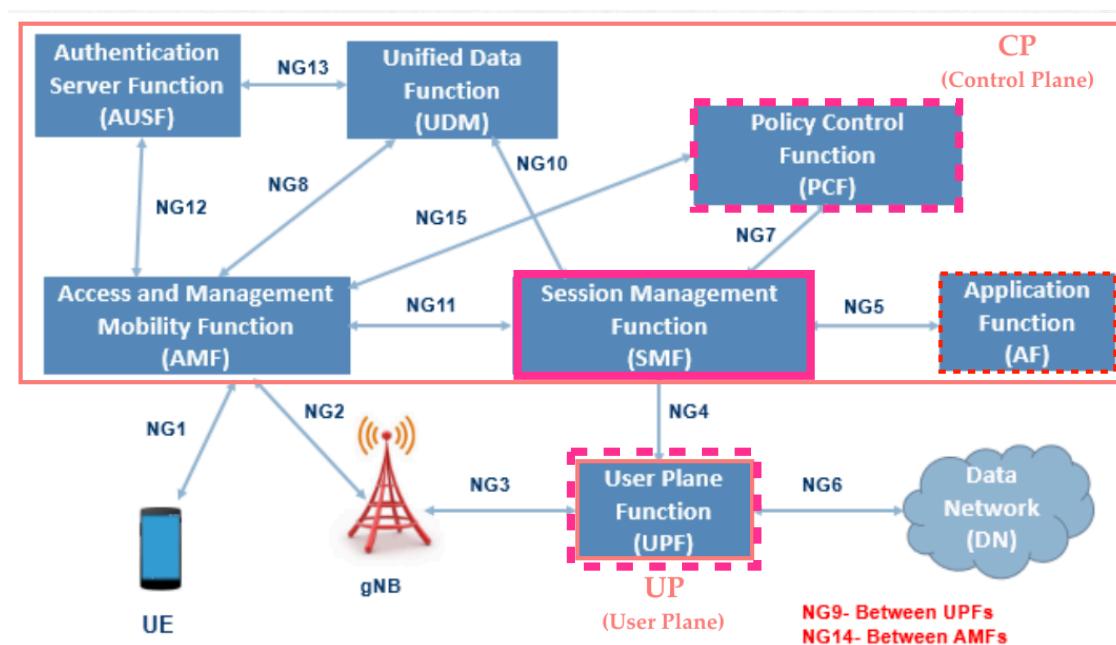


• Session Management Control Function (SMF)

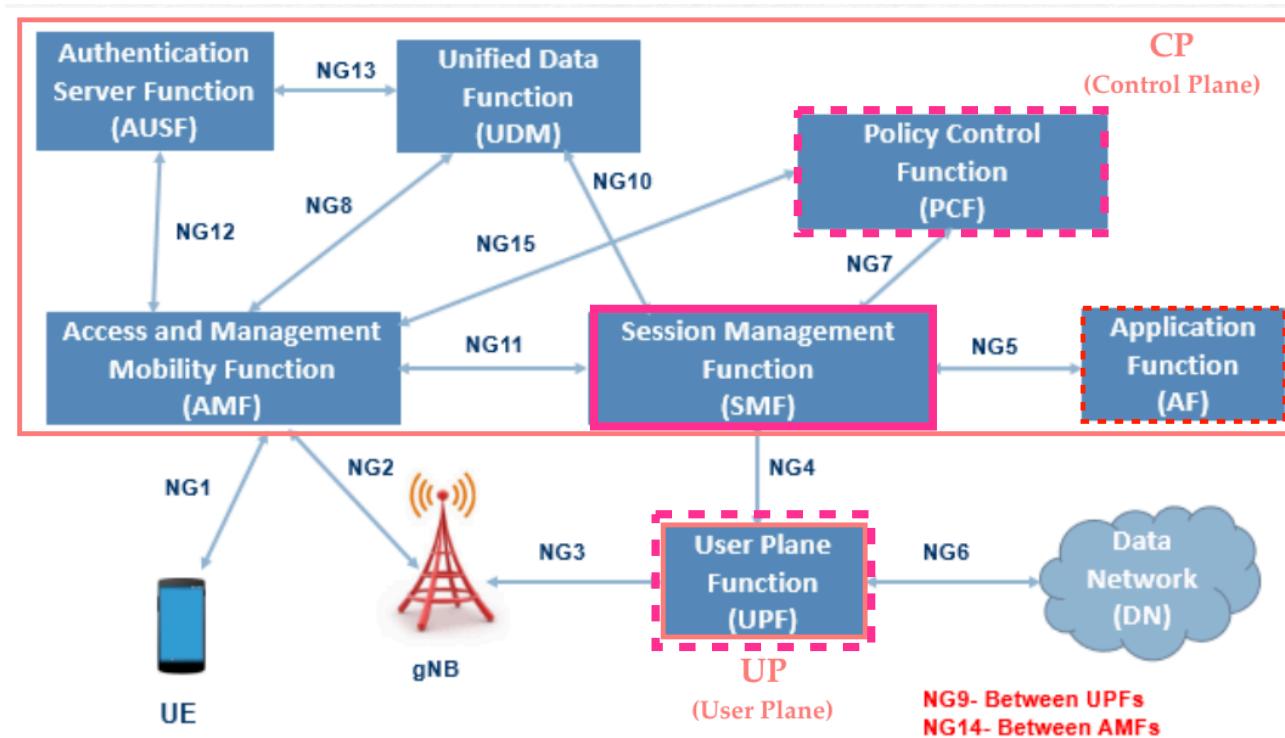
- Session management
- UE IP address allocation & management (including optional authorization)
- Selection and control of User Plane function (UPF)
- Termination of interfaces towards Policy control and Charging functions (PCF)
- Control part of policy enforcement and QoS



- Lawful intercept for session management events and interface to Lawful Intercept System
- Termination of Session Management parts of NAS messages
- Downlink data notification

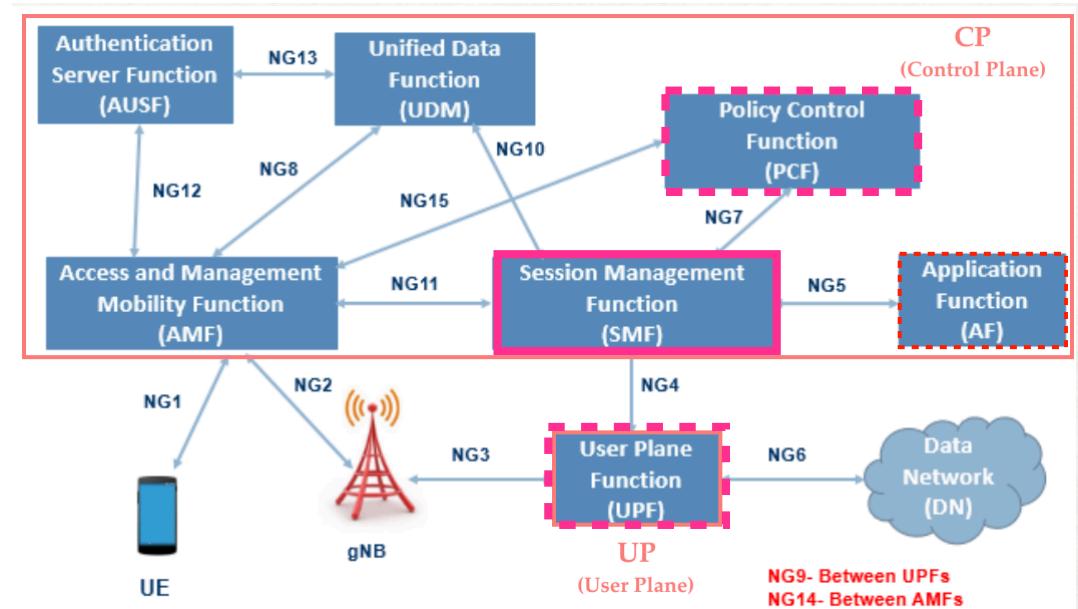


- Initiator of Access Node specific Session Management information, sent via AMF over NG2 to Access Node
- Roaming functionality



- Handle local enforcement to apply QoS SLAs (VPLMN)
- Charging data collection and charging interface (VPLMN)
- Lawful intercept in VPLMN for Session Management events and interface to Lawful Intercept System

VPLMN (**Visited** Public Land Mobile Network) : a PLMN upon which the mobile subscriber has **roamed** when leaving their HPLMN (**Home** Public Land Mobile Network)

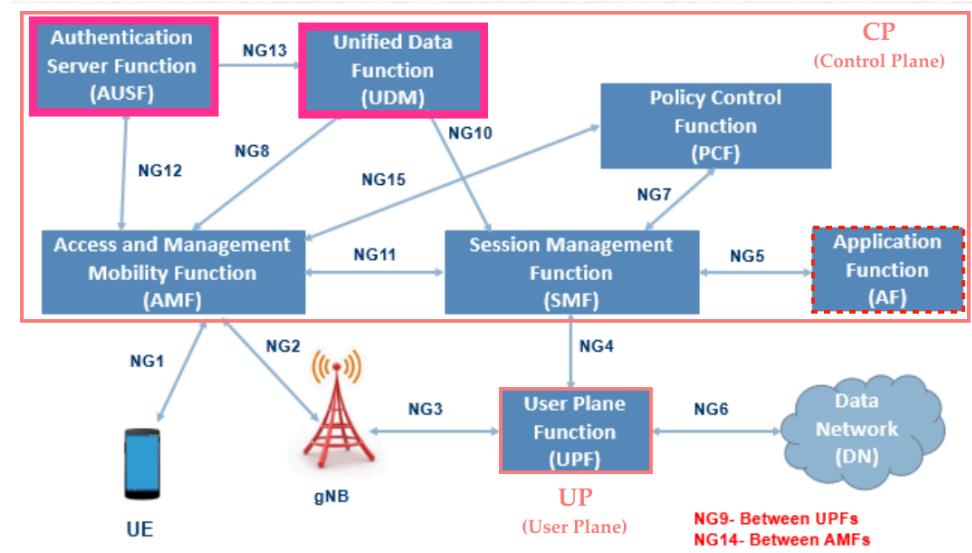


• Authentication Server Function (AUSF)

- Performs authentication processes with UE

• Unified Data Management (UDM)

- Authentication Credential Repository and Processing Function (ARPF); this function stores the long-term security credentials used in authentication for AKA (Authentication and Key Agreement)
- Storing of subscription information

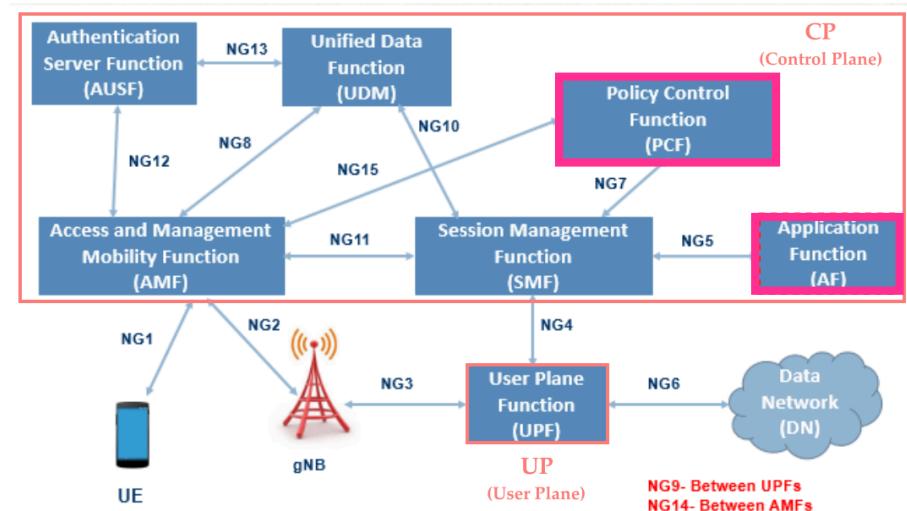


• Policy Control Function (PCF)

- Support of unified policy framework to govern network behavior
- Policy rules to control plane function(s) that enforce them

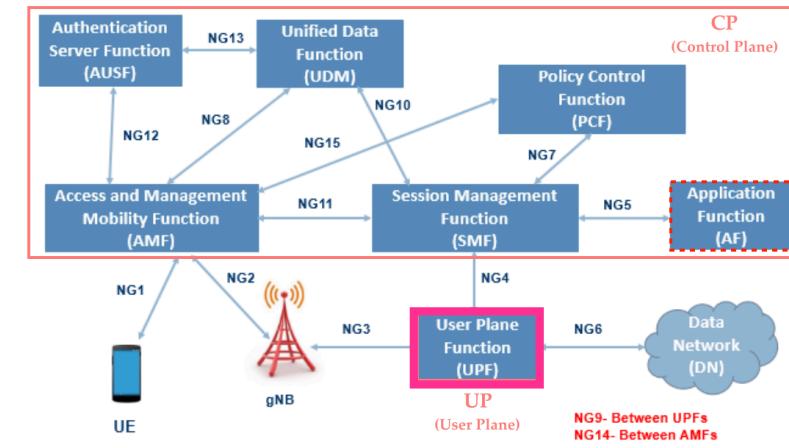
• Application Function (AF)

- Request dynamic policies and/or charging control

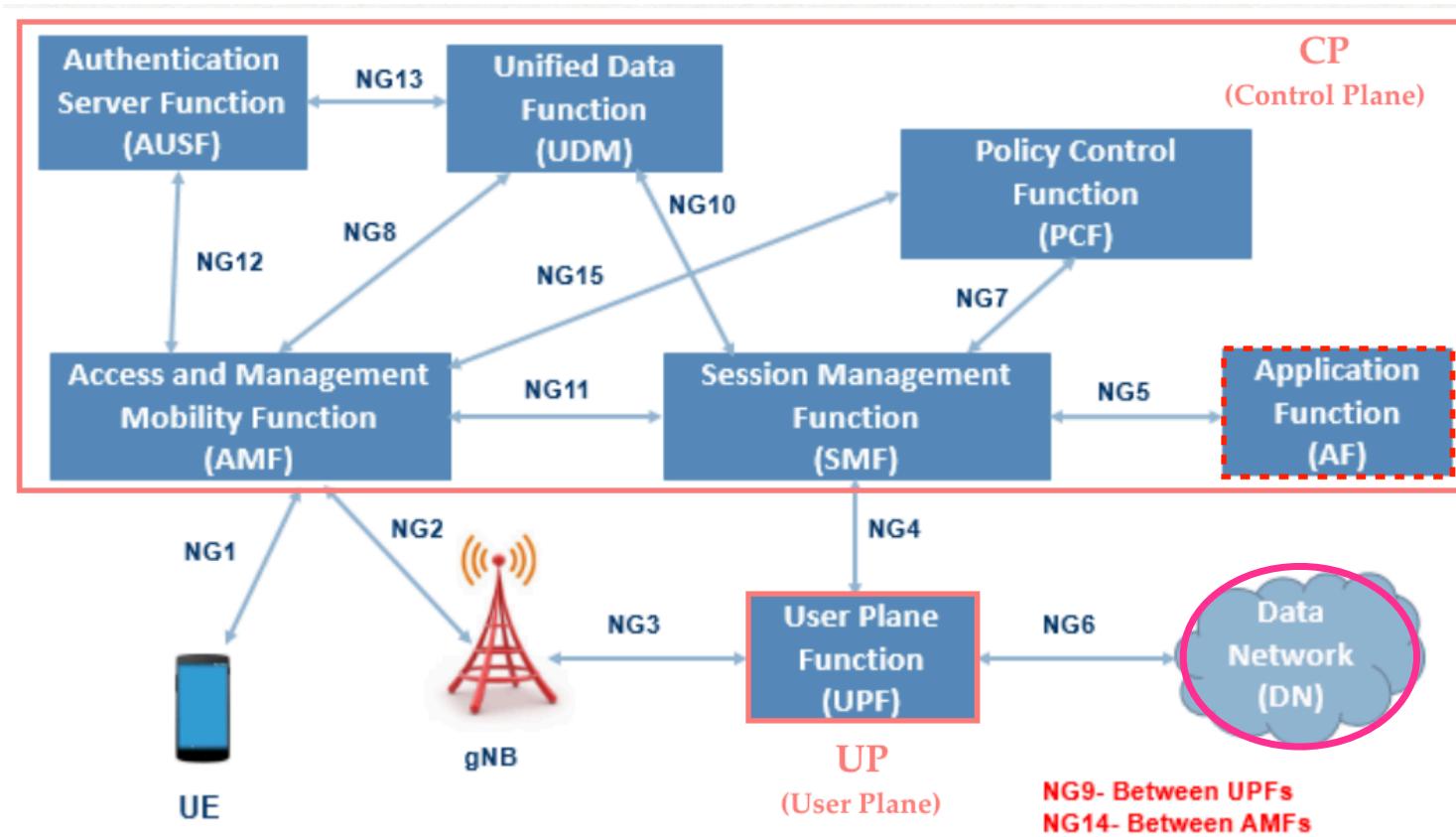


• User plane Function (UPF)

- QoS handling for User Plane
- Packet routing & forwarding
- Packet inspection and policy rule enforcement
- Lawful intercept (User Plane)
- Traffic accounting and reporting
- Anchor point for Intra-/Inter-RAT mobility (when applicable)
- Support for interaction with external DN for transport of signaling for PDU (Protocol Data Unit) session authorization/authentication by external DN

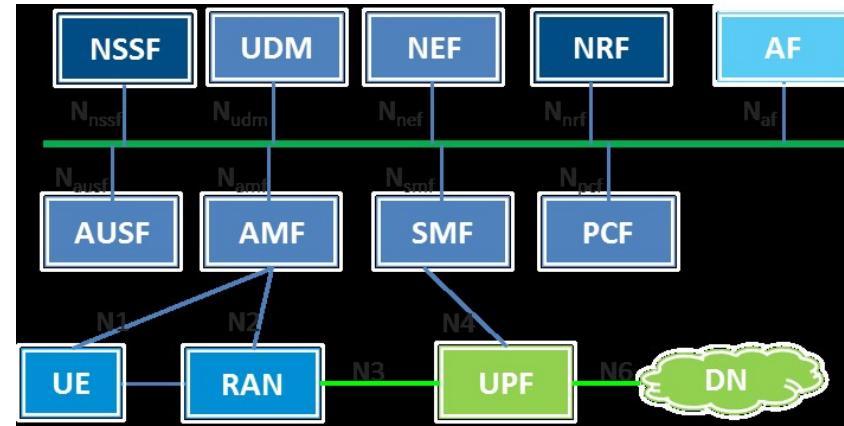


- **Data Network (DN)**
- Operator services, Internet access or other services

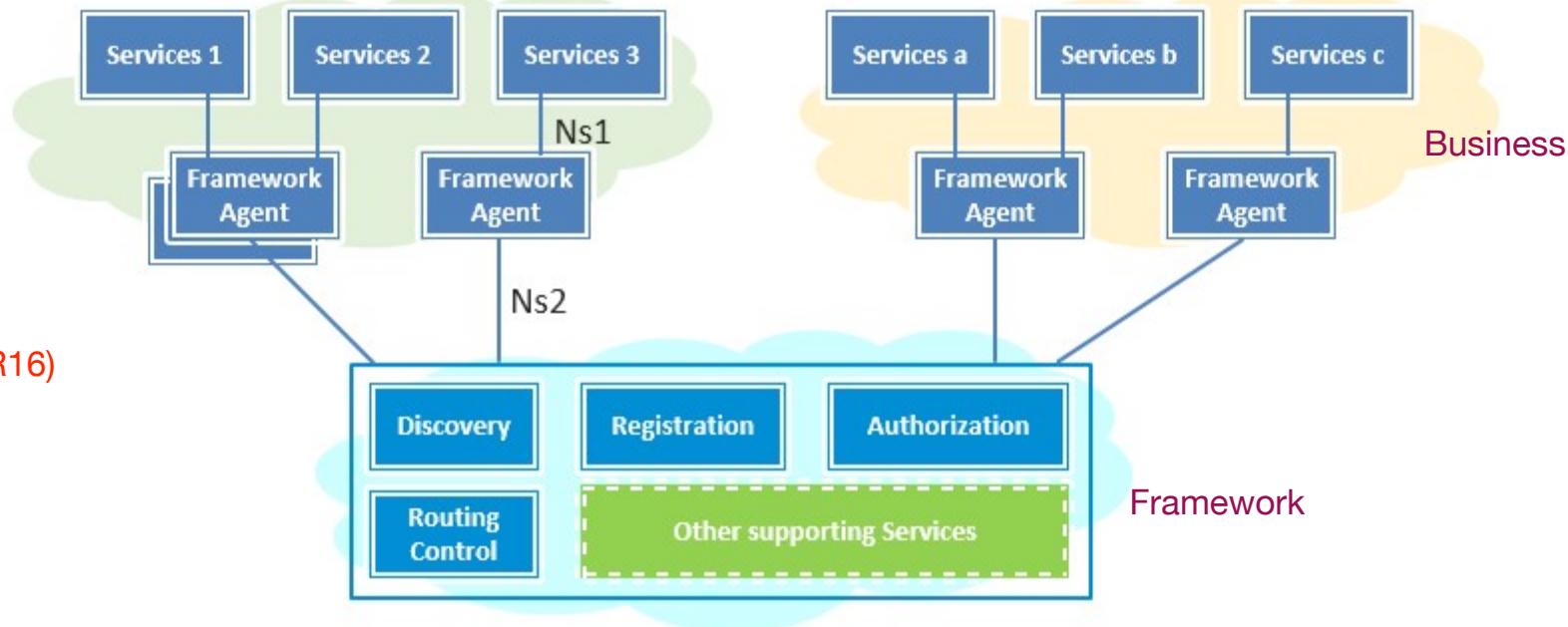


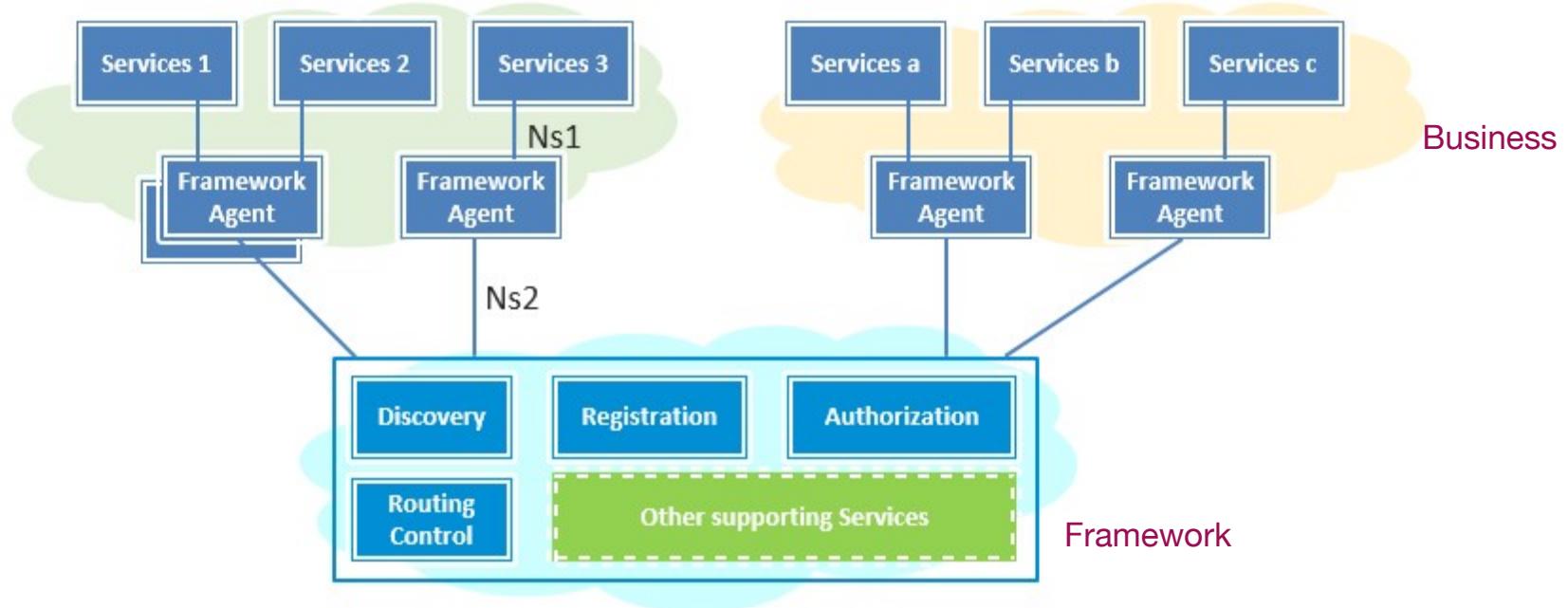
Enhanced SBA (eSBA)

3GPP SBA (R15)



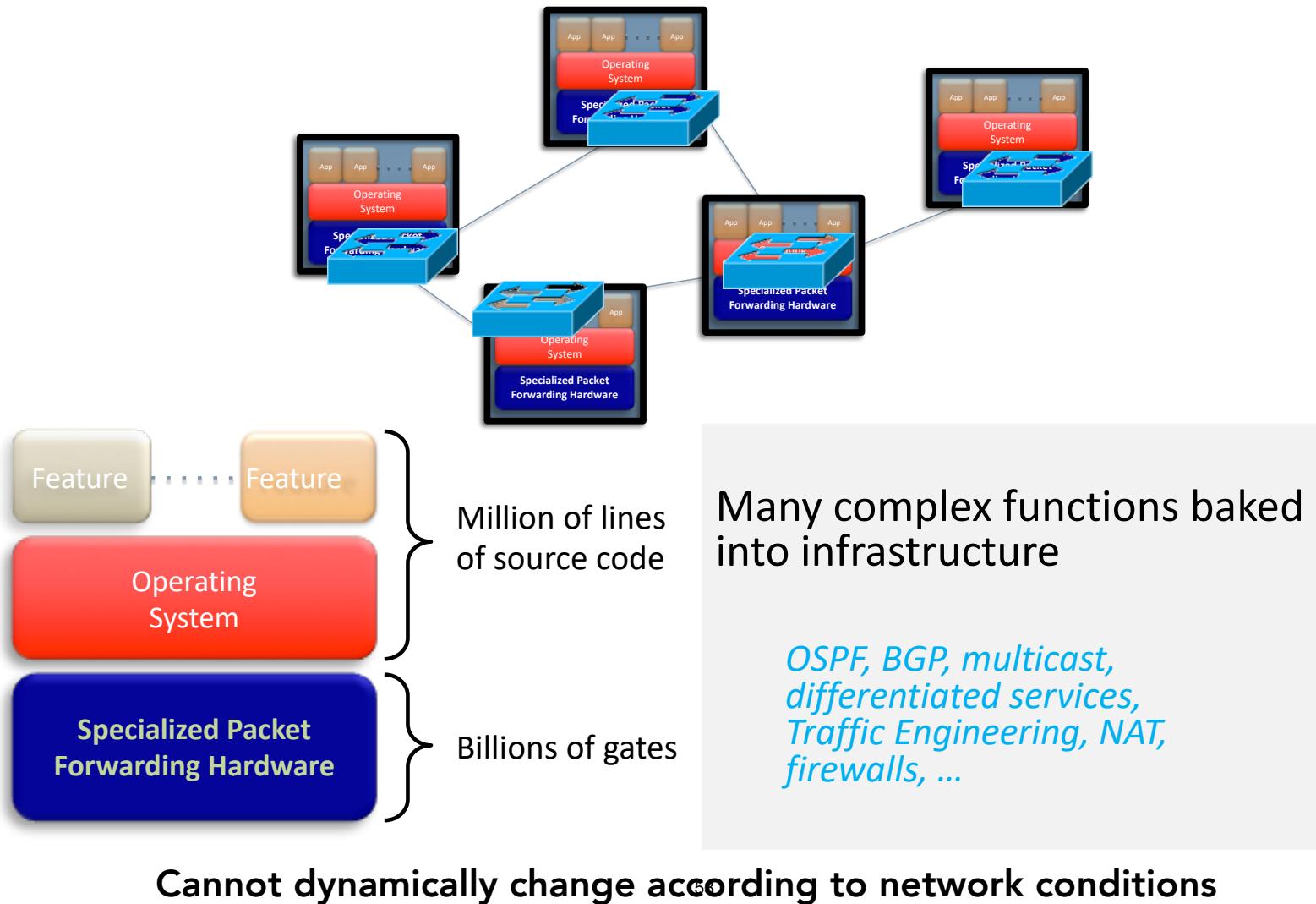
3GPP eSBA (R16)





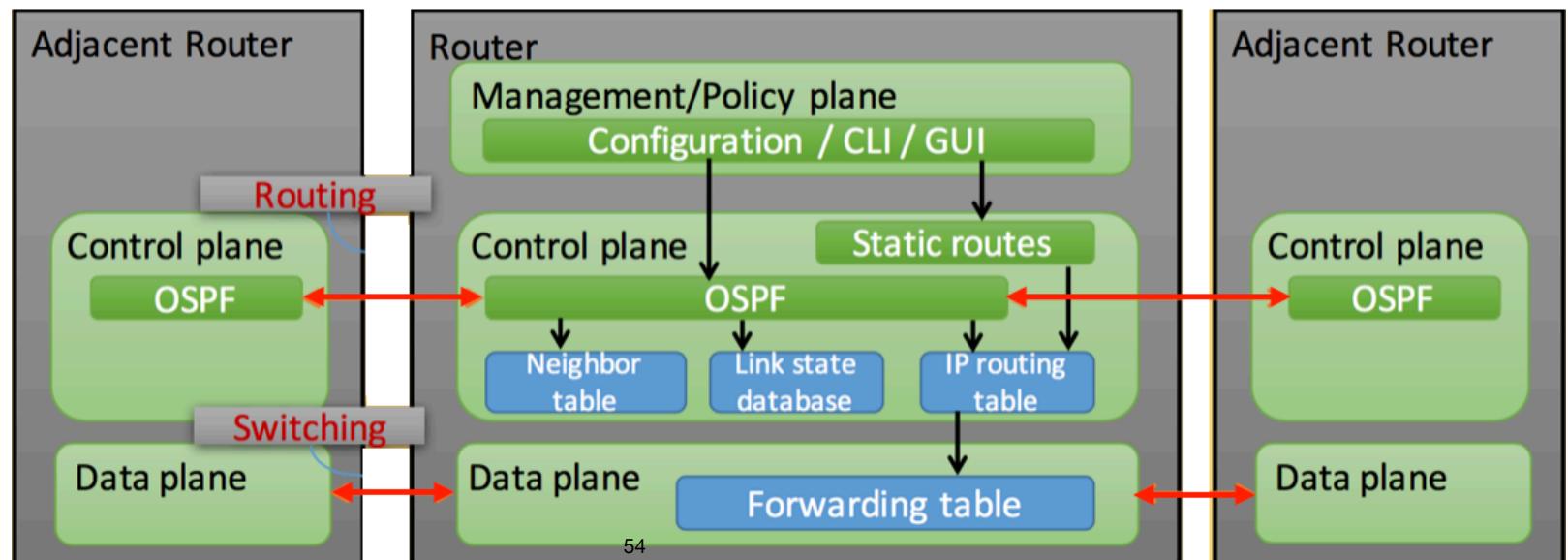
- The **business** (business logic) and **framework** (framework proxies) are decoupled
- The framework performs function reconstruction
 - Basic functions: service discovery, registration, authentication, and routing control
 - Serve all businesses through the framework proxies

Traditional Network → Software Defined Network

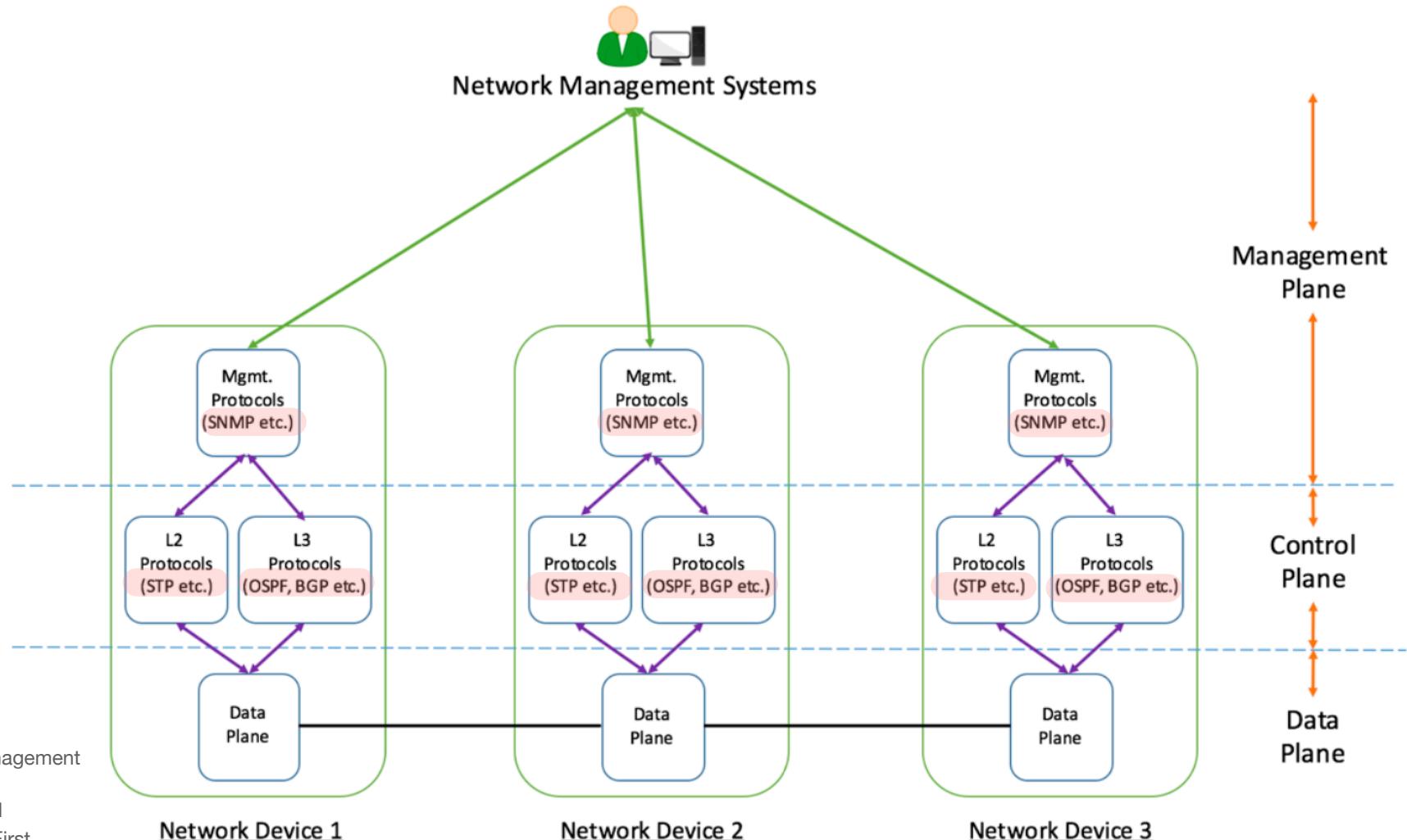


Traditional Network Router

- **Management plane:** collect measurements and configure the equipment
- **Control plane:** track topology changes, compute routes, install forwarding rules, e.g. OSPF (Open Shortest Path First)
- **Data plane:** forward, filter, buffer, mark, rate-limit, and measure packets

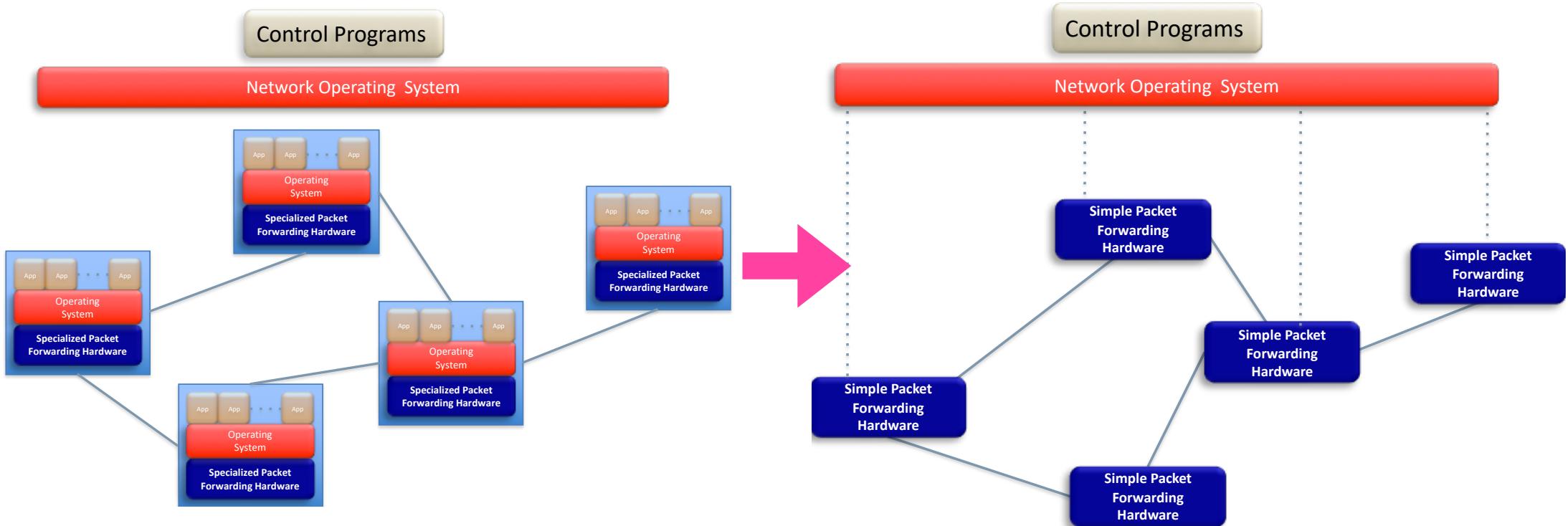


Traditional Network Architecture

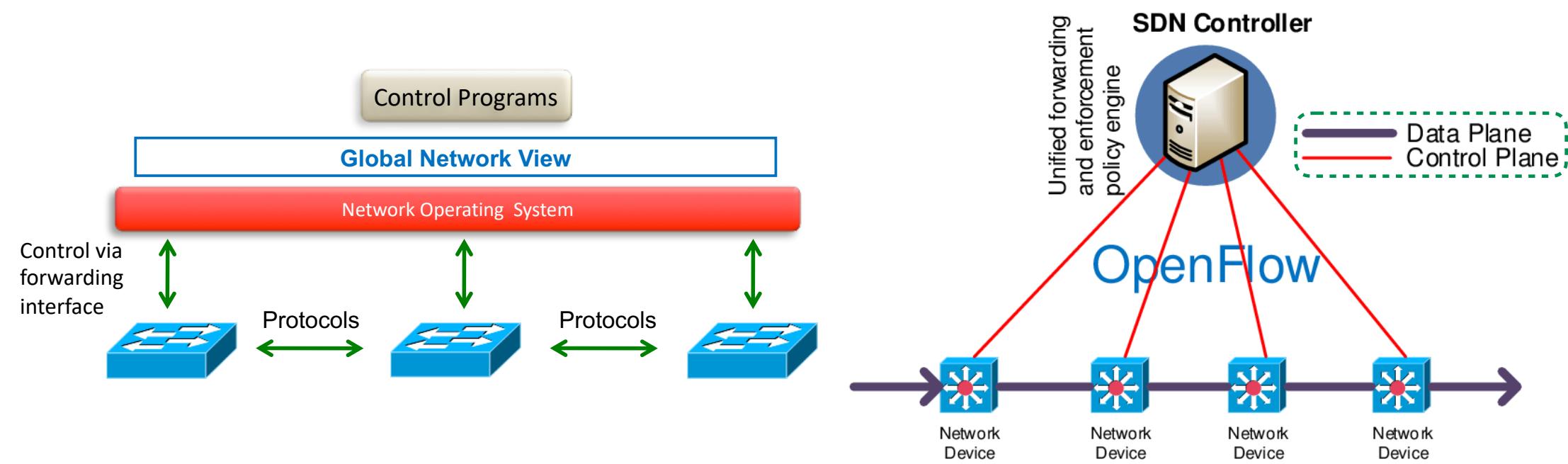


- **Problems**
 - Closed equipment
 - Software bundled with hardware
 - Vendor-specific interfaces
 - Slow protocol standardization
 - Few people can innovate
 - Equipment vendors write the code
 - Long delays to introduce new features
 - Impact performance, security, reliability, cost, etc.

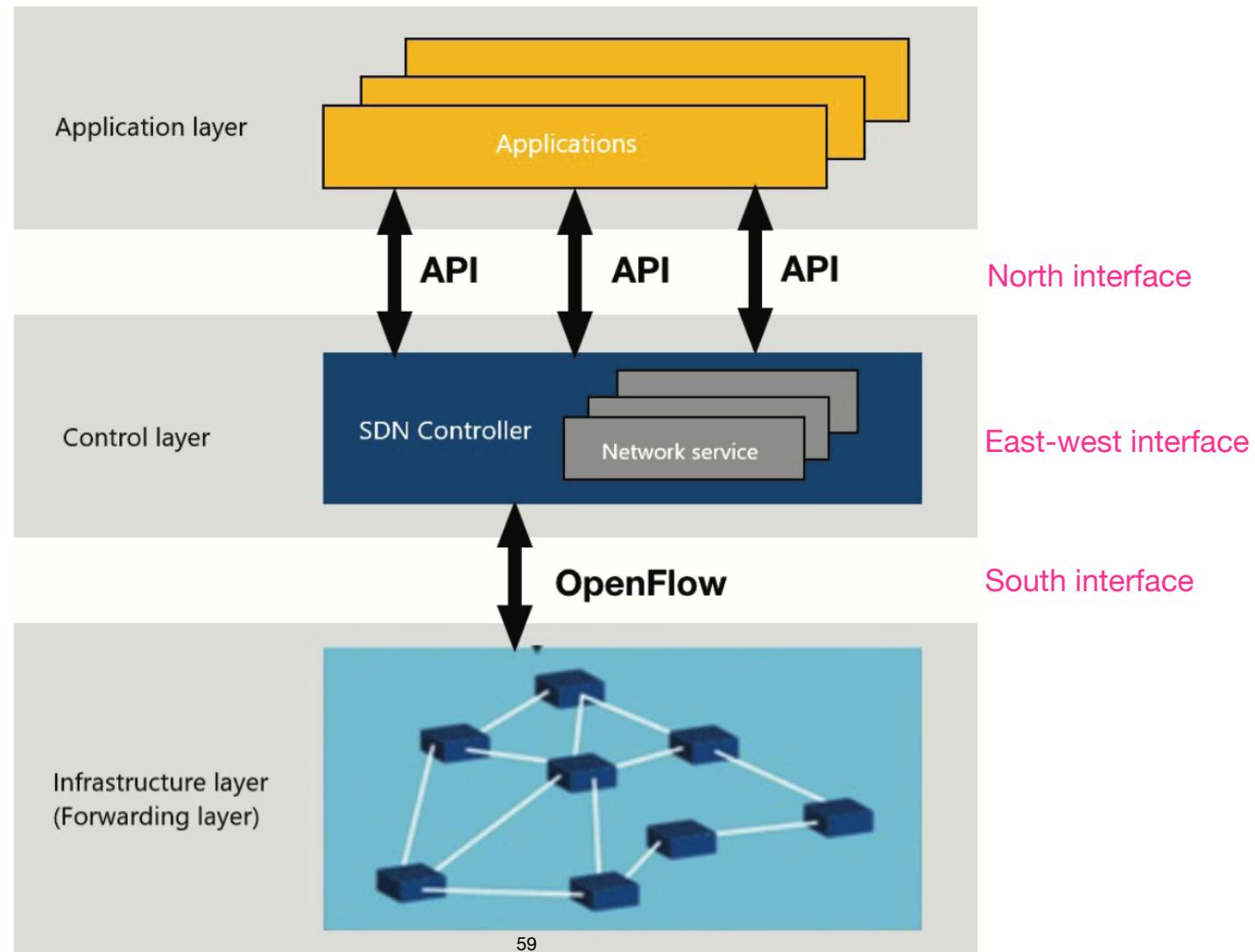
Idea – An OS for Networks

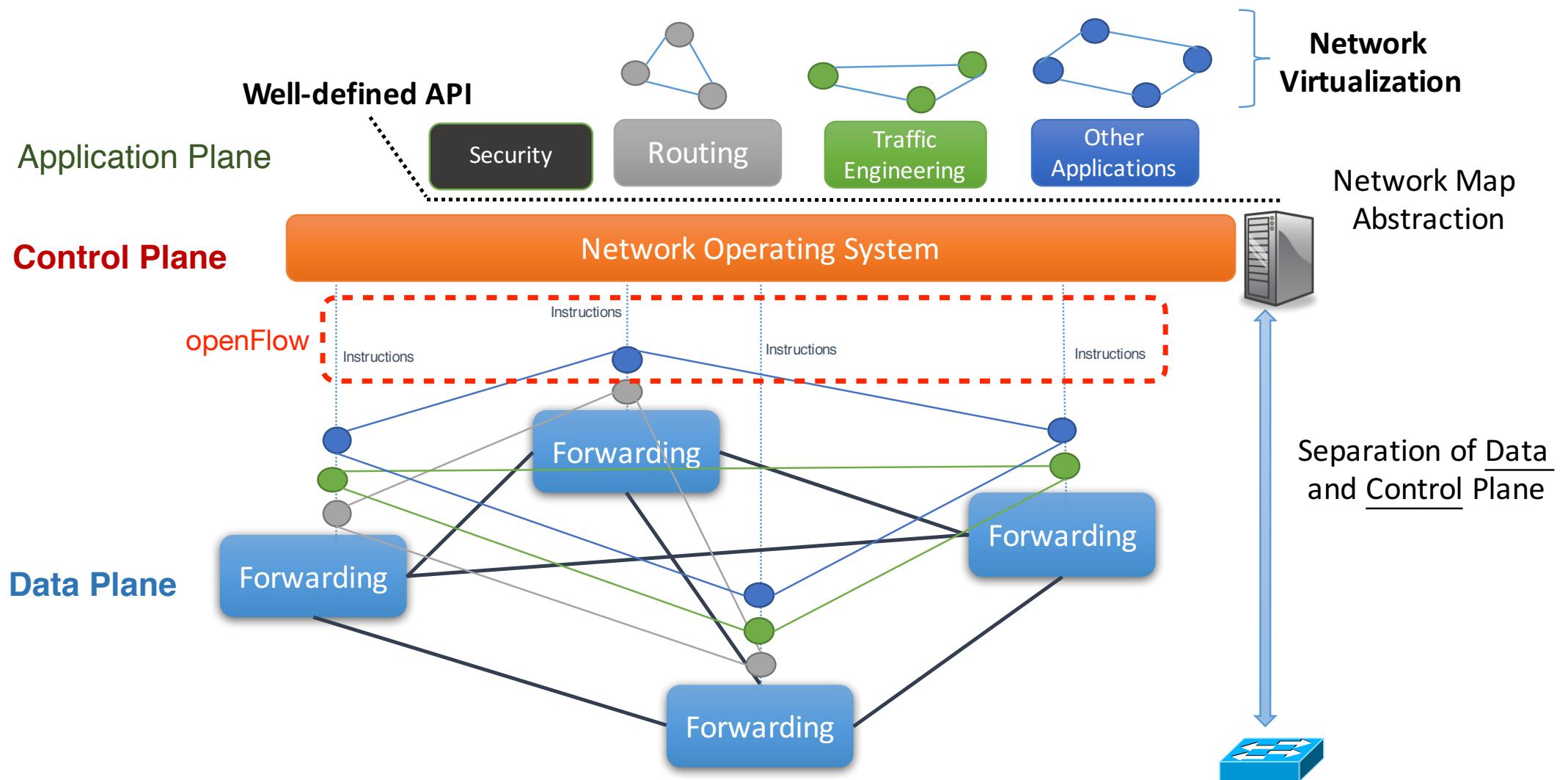


Software-Defined Networking (SDN)



SDN Architecture





Specifies behavior

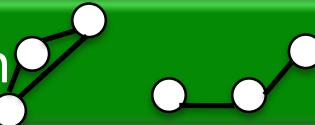
Control Program

e.g. routing,
access control

Abstract Network Model

Compiles to topology

Network Virtualization

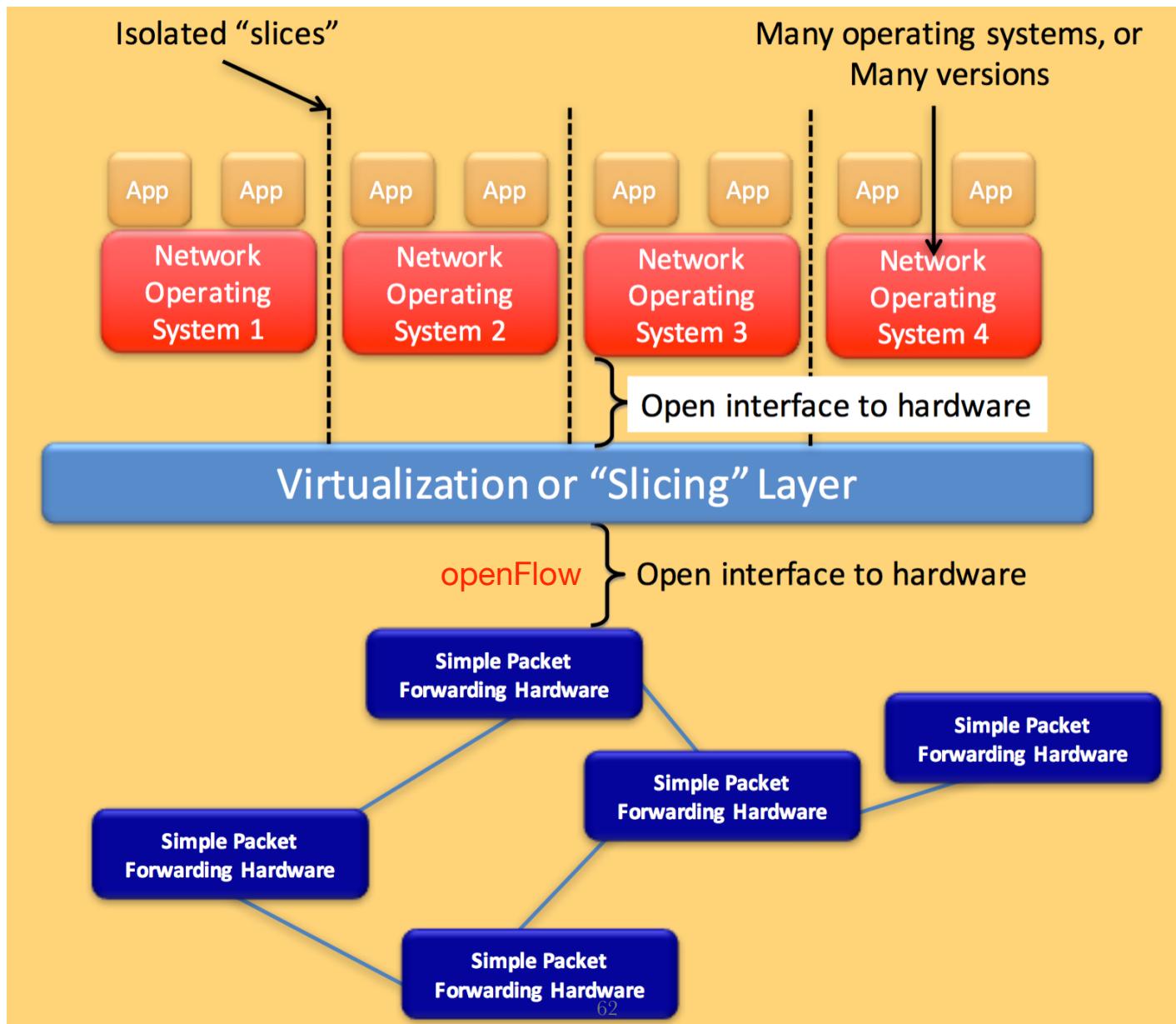


Global Network View

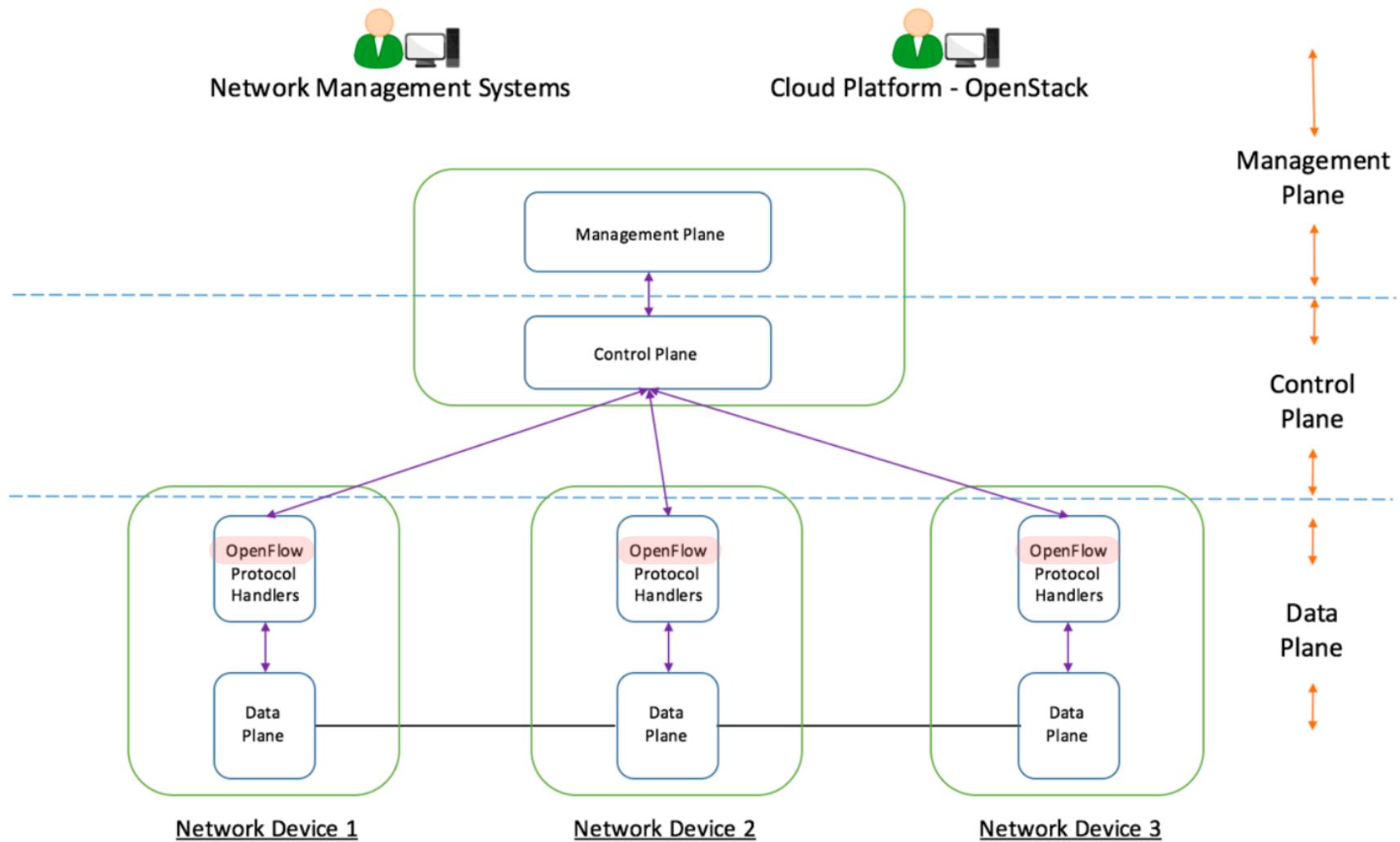
Transmits to switches

Network OS



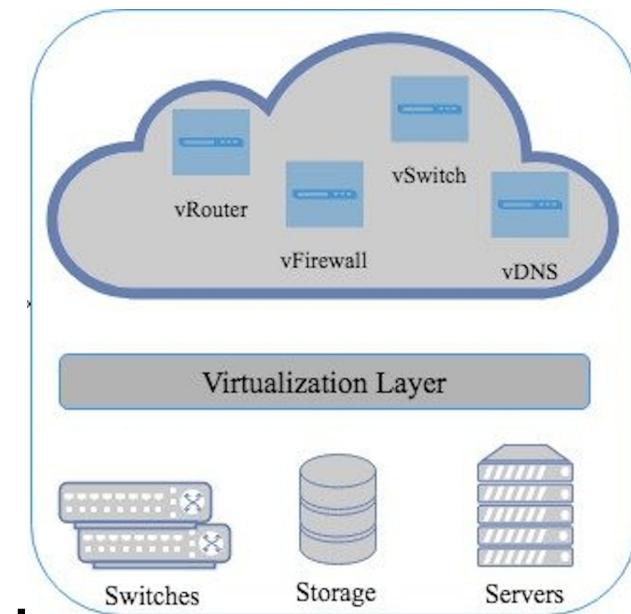


Simplified SDN-based Network Architecture

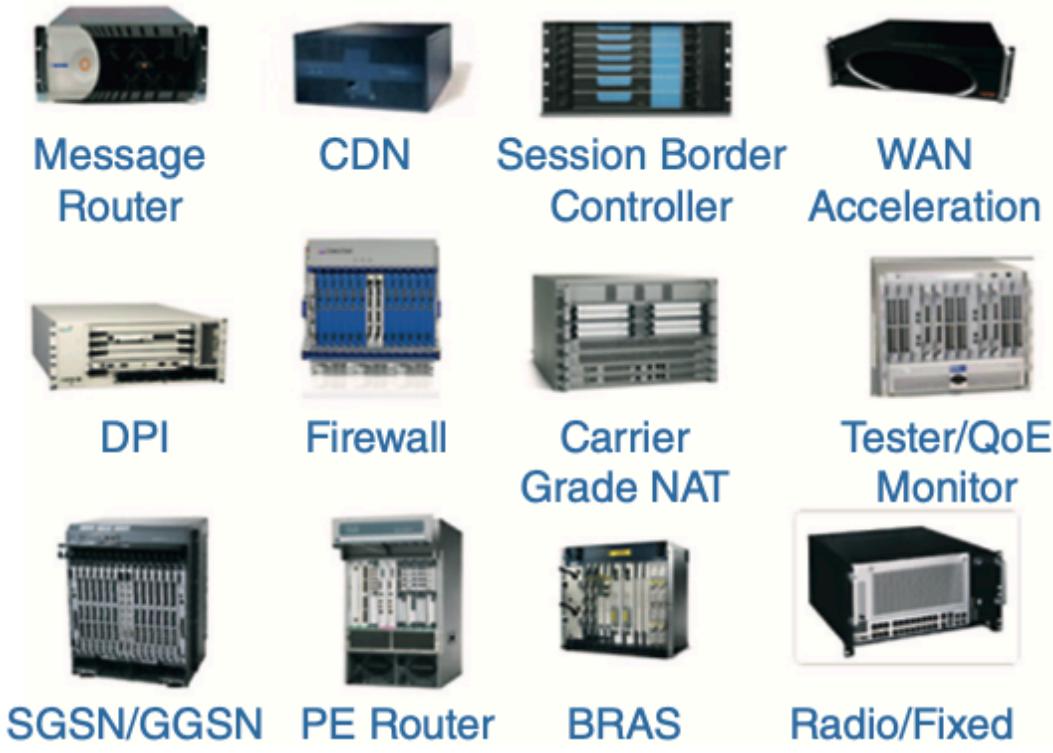


Network Functions Virtualization (NFV)

- Virtualize entire network node functions onto industry standard high volume servers, switches and storage, which could be located in data centers or centralized locations
- Implement network functions in a software that can run on a range of industry standard server hardware, and that can be moved to, or instantiated in, various locations in the network



Classical Network Appliance Approach

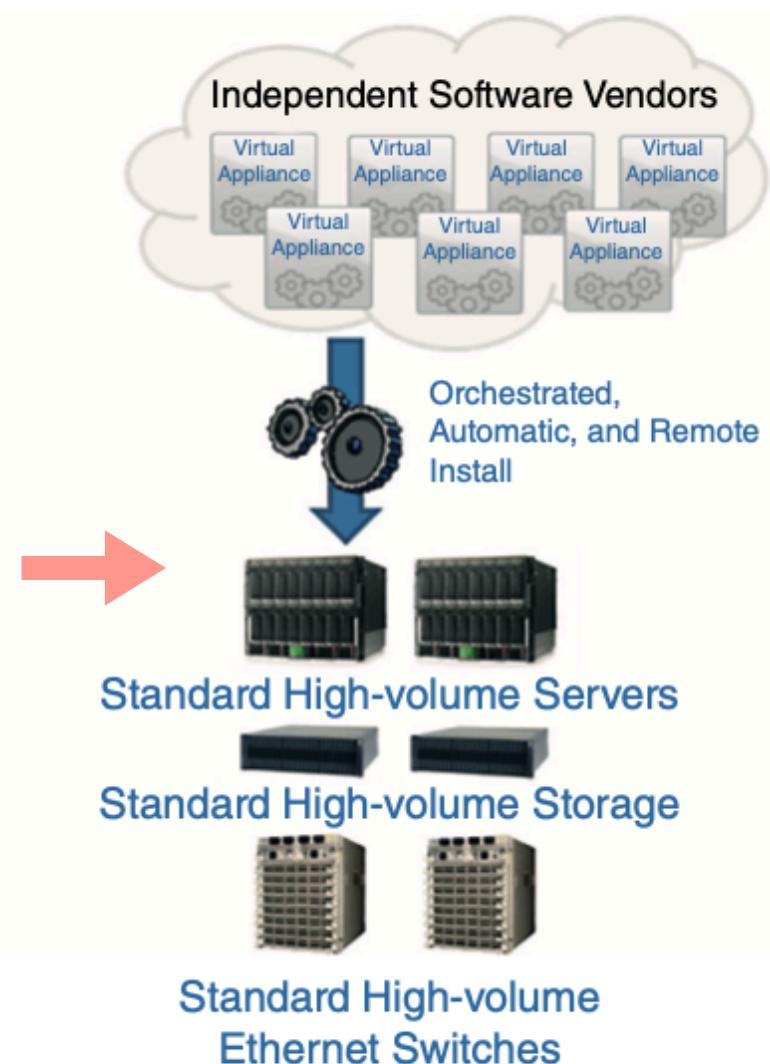


CDN : Content Delivery Network

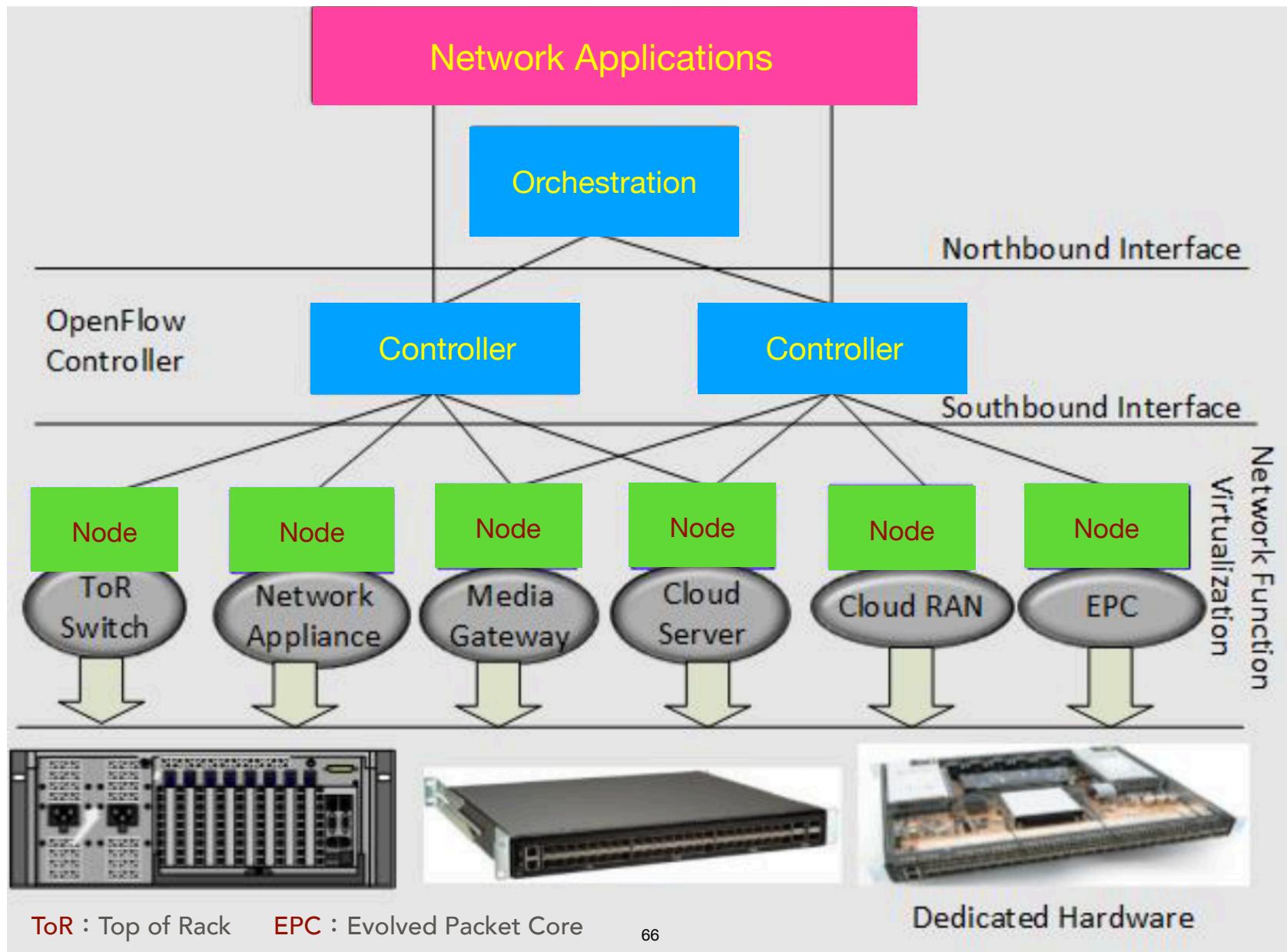
DPI : Deep Packet Inspection

NAT : Network Address Translation

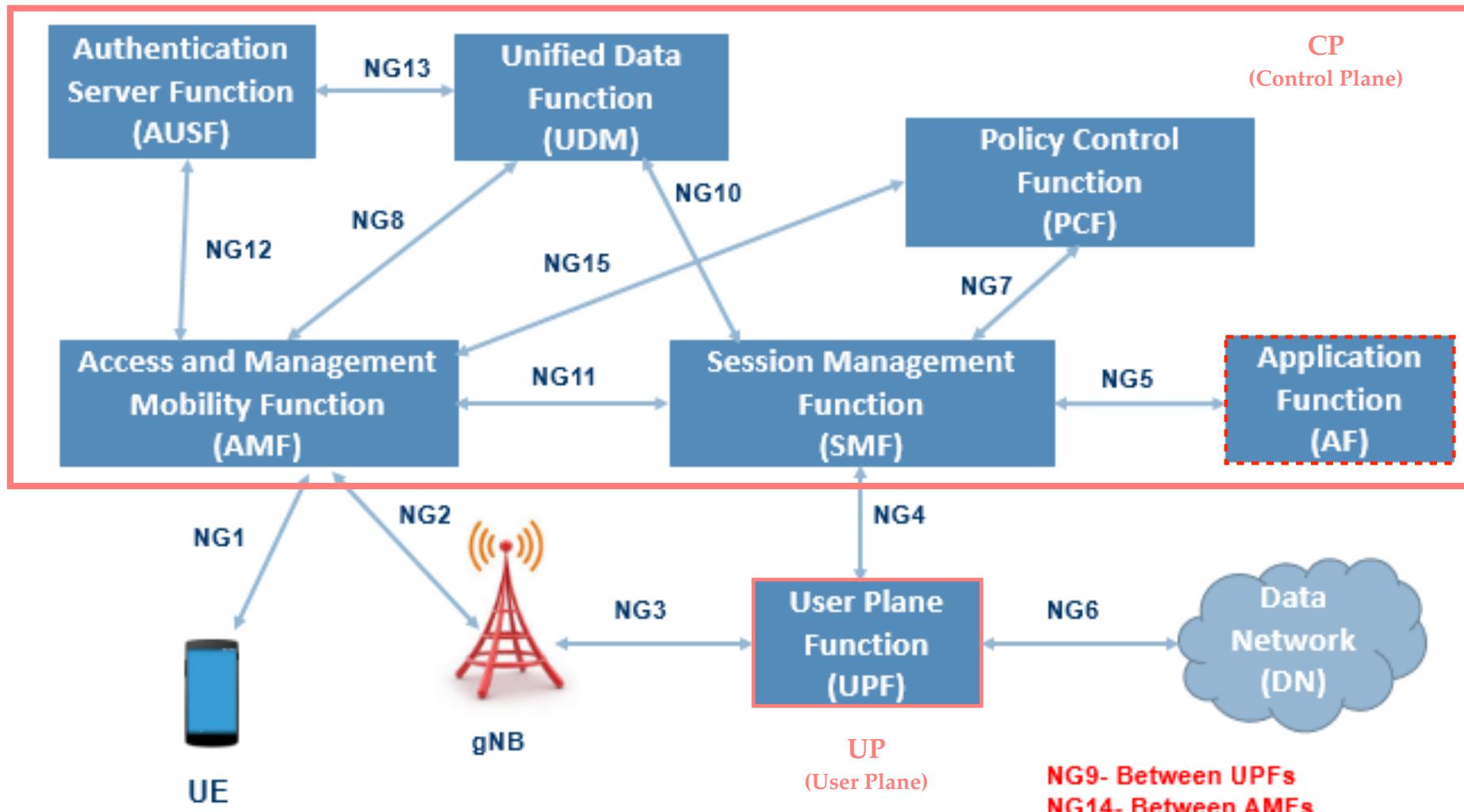
BRAS : Broadband Remote Access Server



Network Virtualization Approach



5G Network Architecture

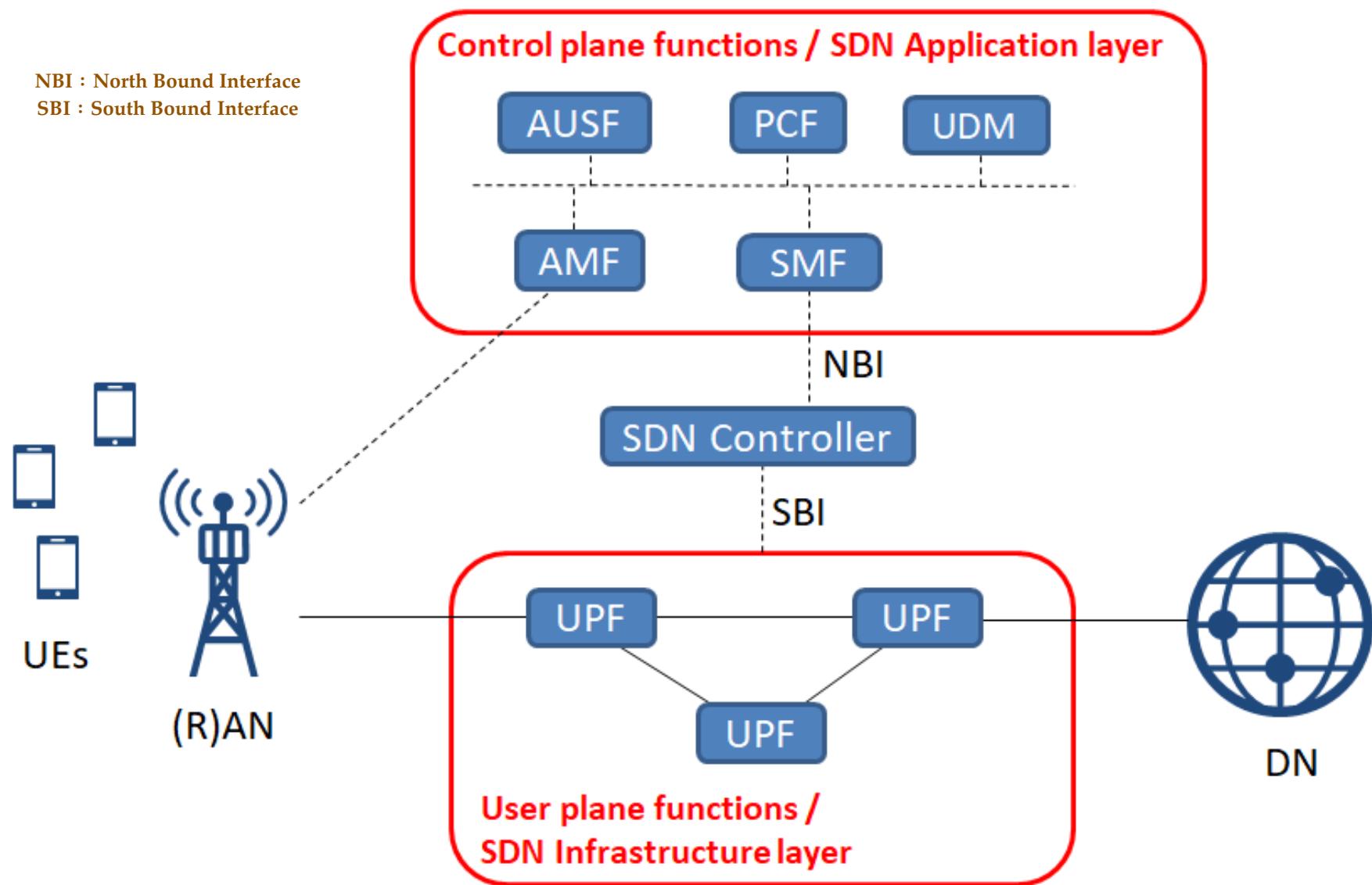


UE : User Equipment

gNB : Next Gen Node Basestation

Source 3GPP TR 23.799

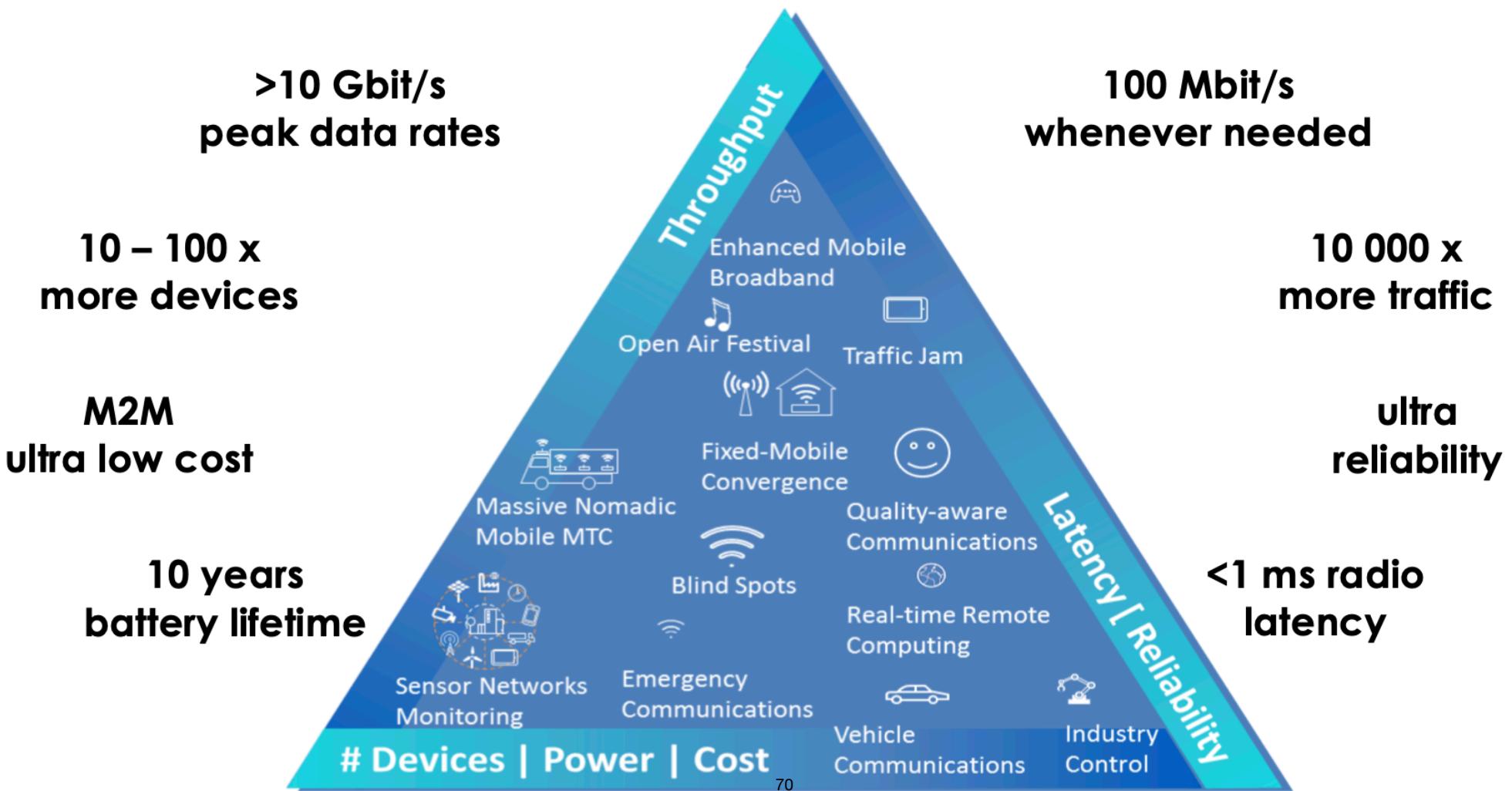
NBI : North Bound Interface
SBI : South Bound Interface



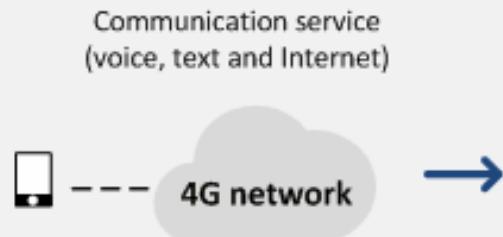
Network Slicing

- 5G services requirements: heterogeneity
 - **Enhanced Mobile Broadband**
 - Deal with hugely increased data volumes, overall data capacity and user density
 - **Massive Machine-type Communications for the IoT**
 - Requiring low power consumption and low data rates for very large numbers of connected devices
 - **Ultra-reliable and Low Latency Communications**
 - Cater for safety-critical and mission critical applications

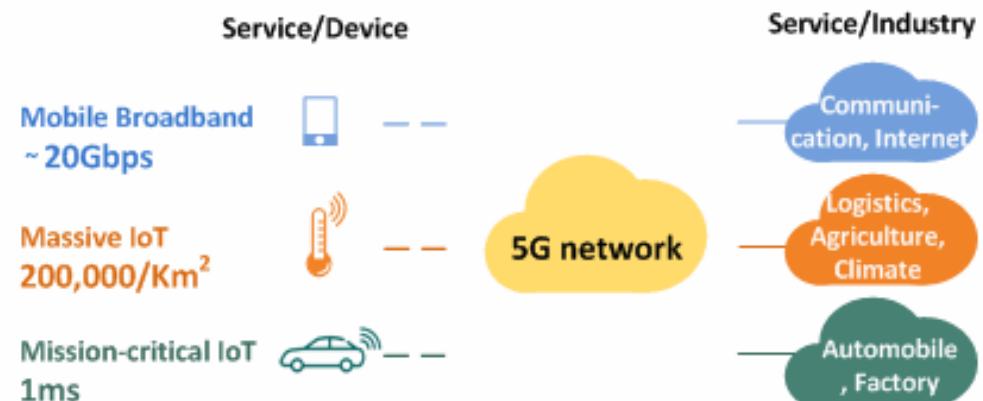
Requirements: Heterogeneity



4G Network: communication service via phones in the communication industry

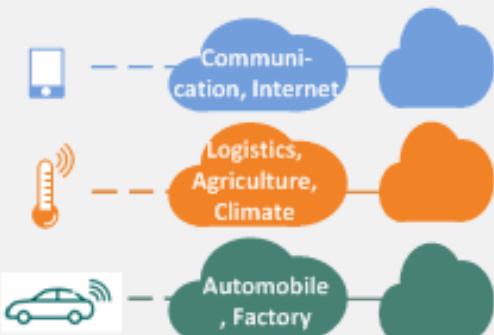


5G network: all mobile services via all types of devices across all industries

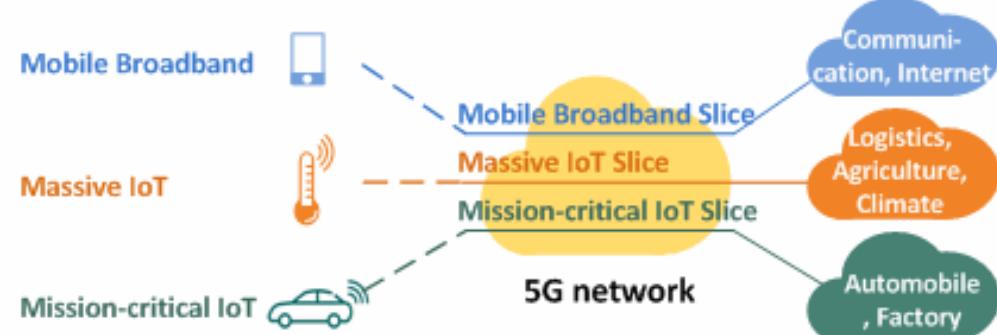


↓ how?

Multiple 5G networks ? X



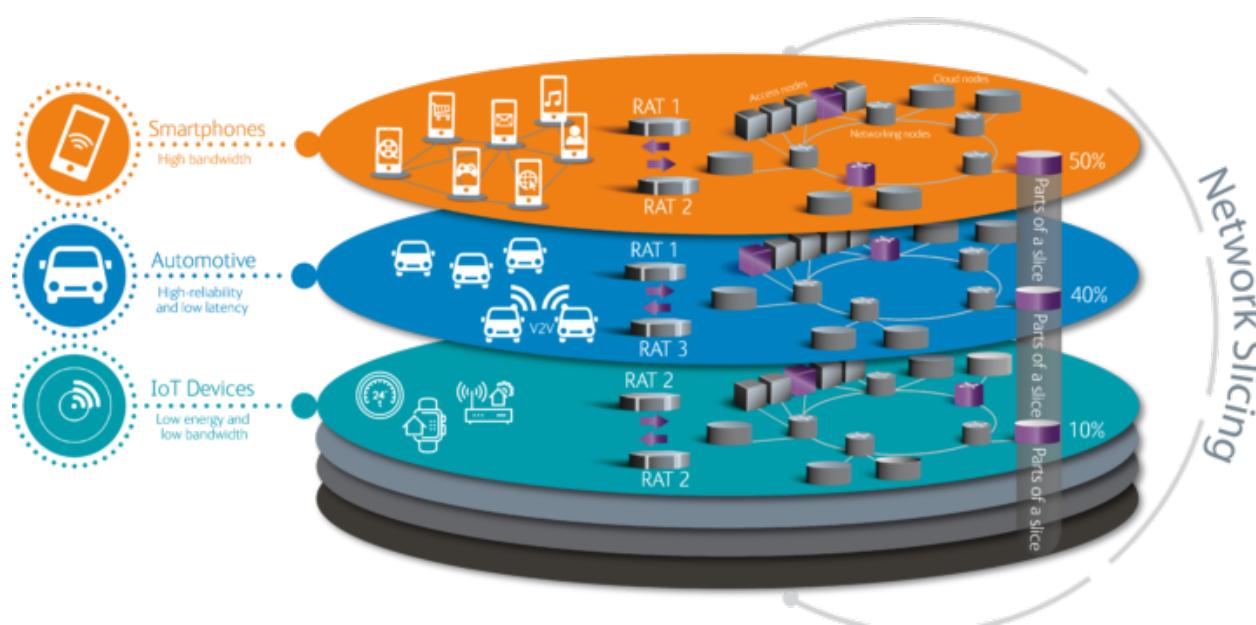
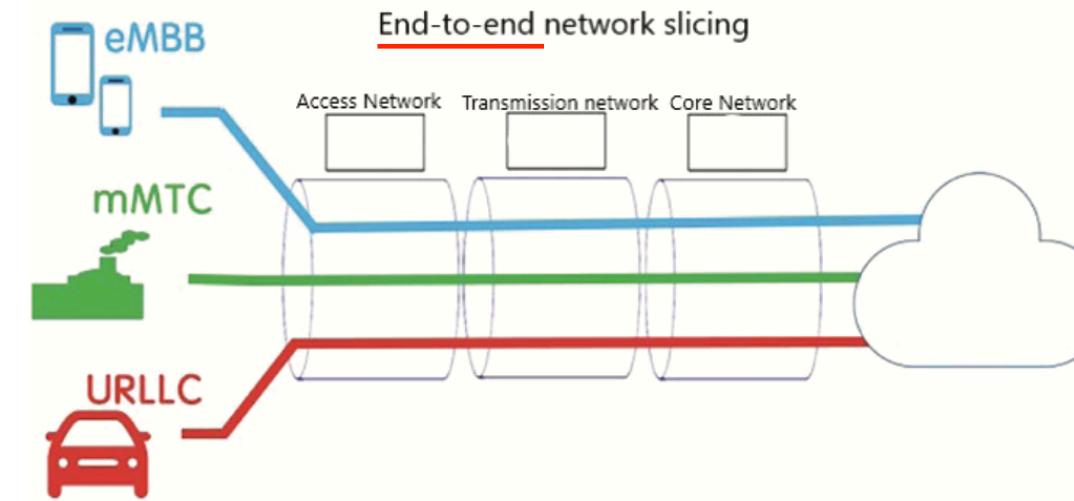
Network Slicing !

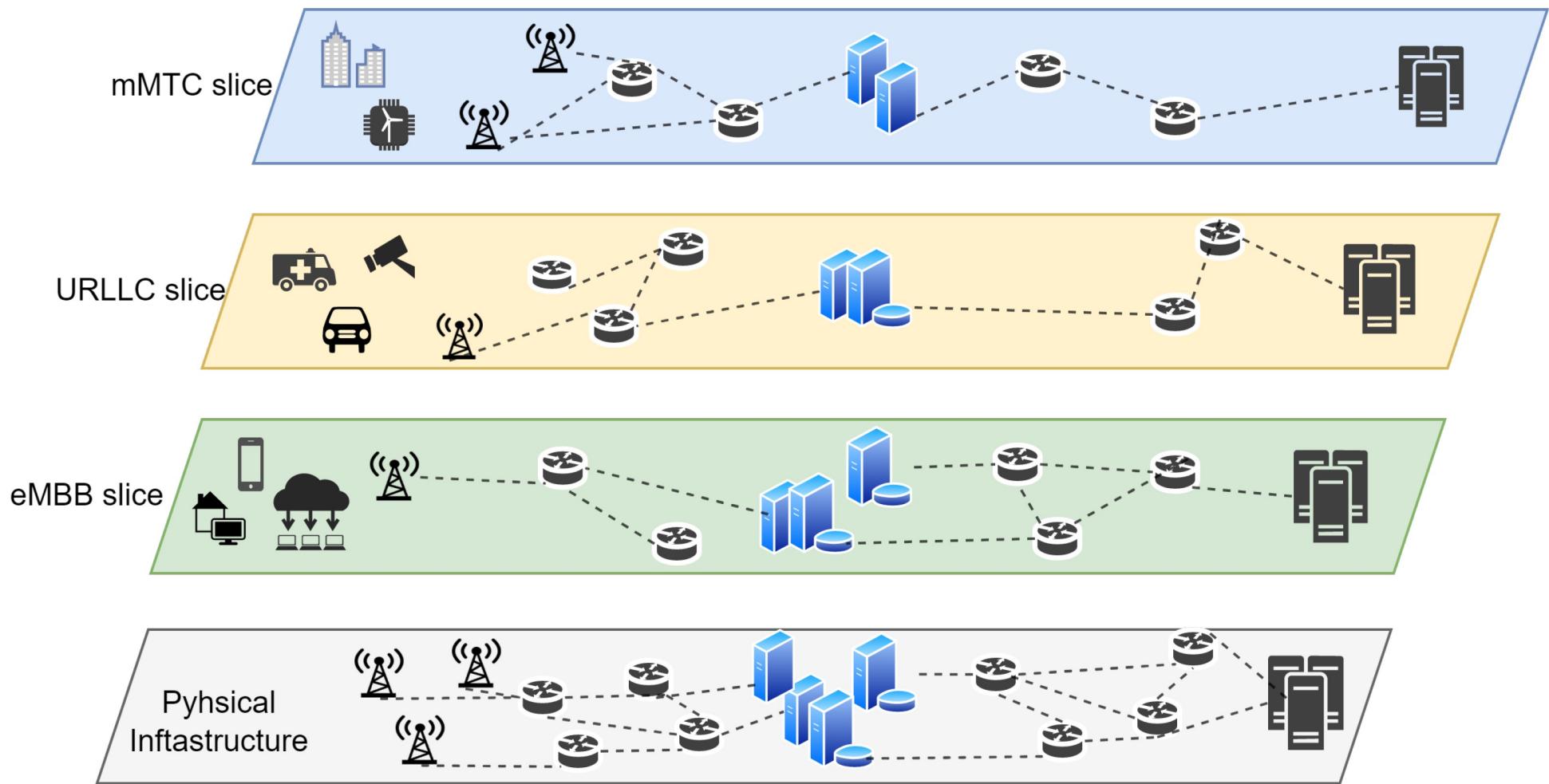


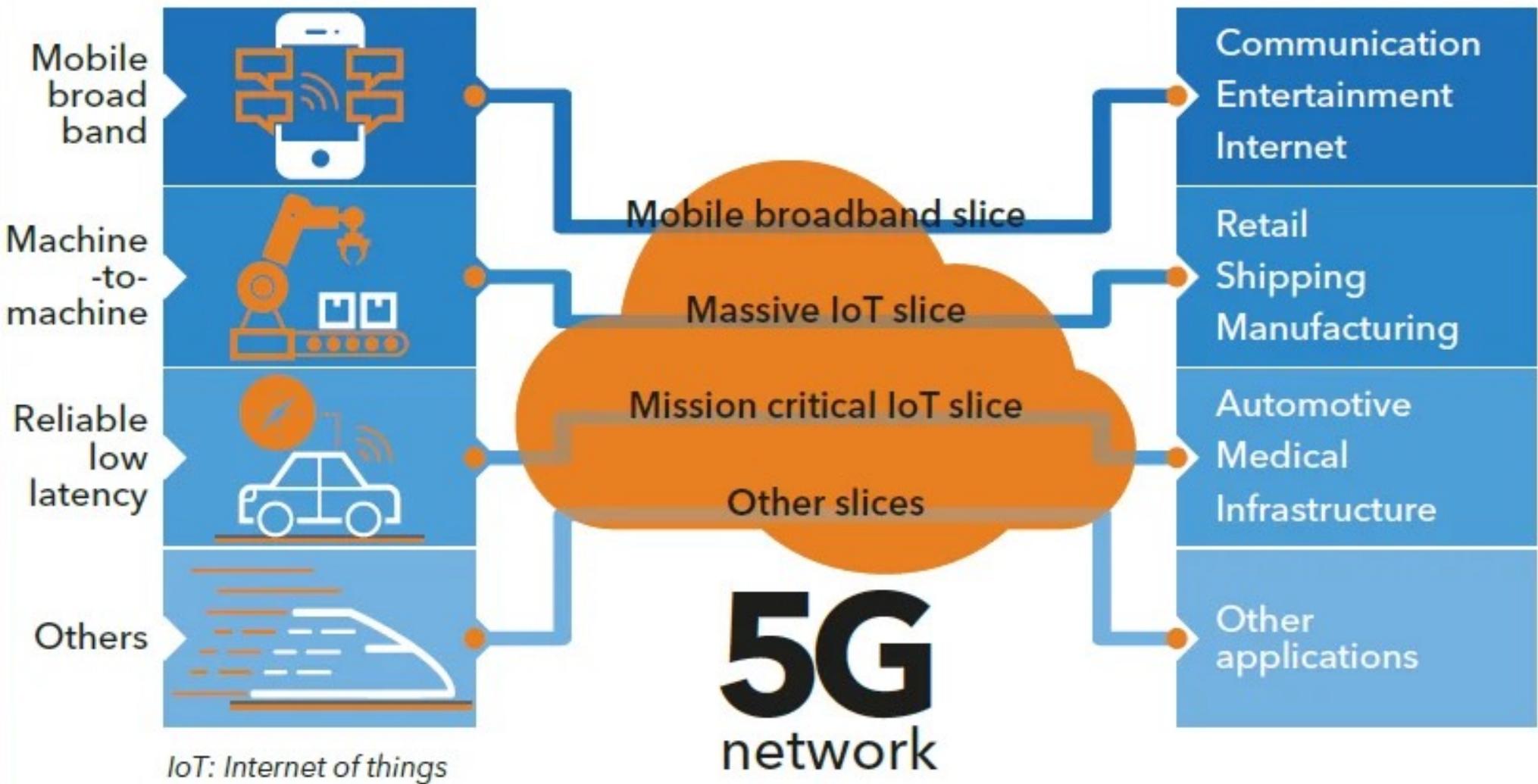
What is Network Slicing?

- **Network slice**
 - A set of infrastructure resources and service functions that has attributes specifically designed to meet the needs of an industry vertical or a service
- **Network slicing**
 - A management mechanism that Network Slice Provider can use to allocate dedicated infrastructure resources and service functions to the users of the network slice

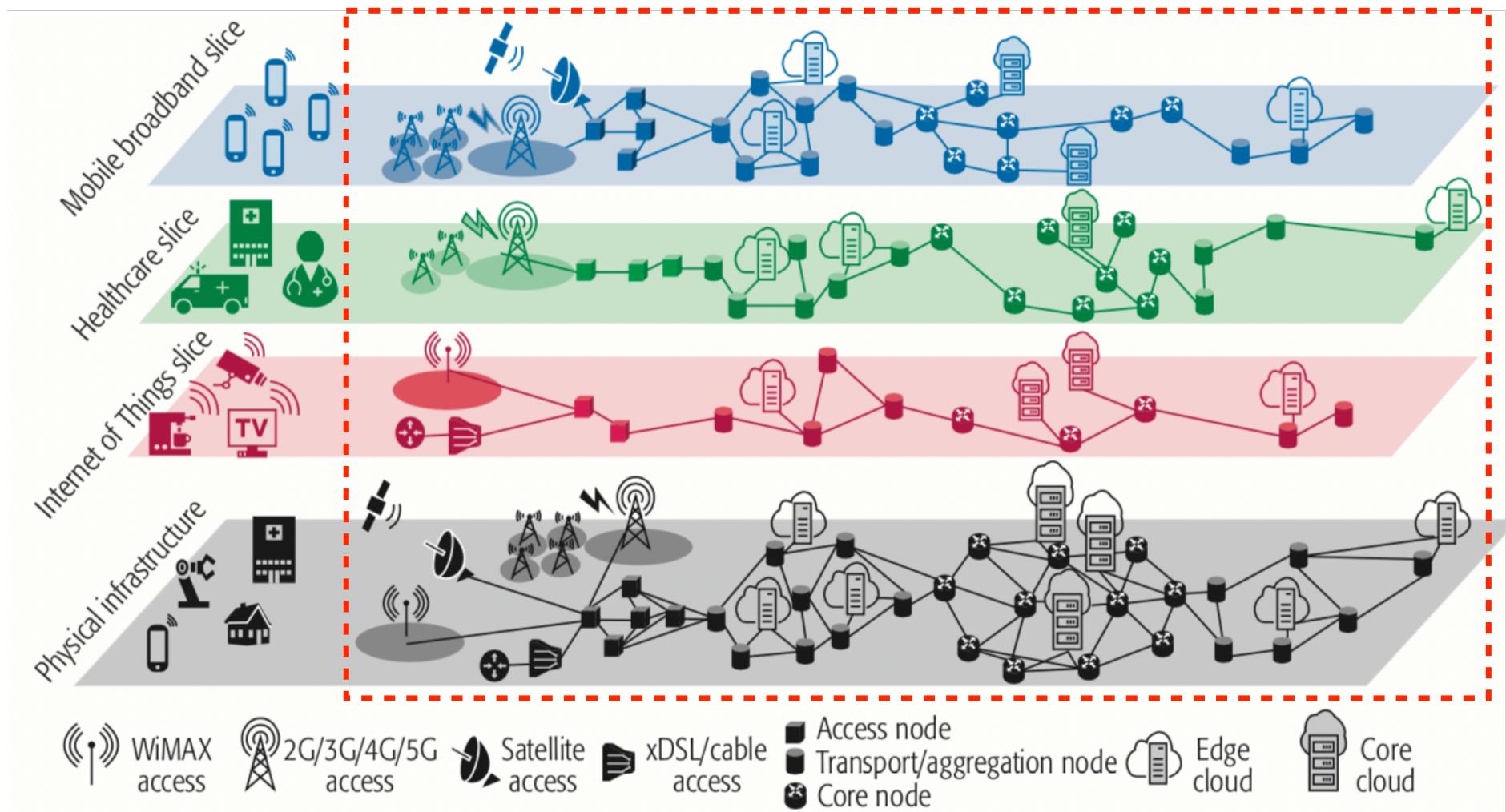
Slicing







Challenge: In One Network



Customization over One Network

Level 3:
Management
Orchestration

E2E Service Management and Orchestration

Access Mgmt.

Cloud Mgmt.

WAN Mgmt.

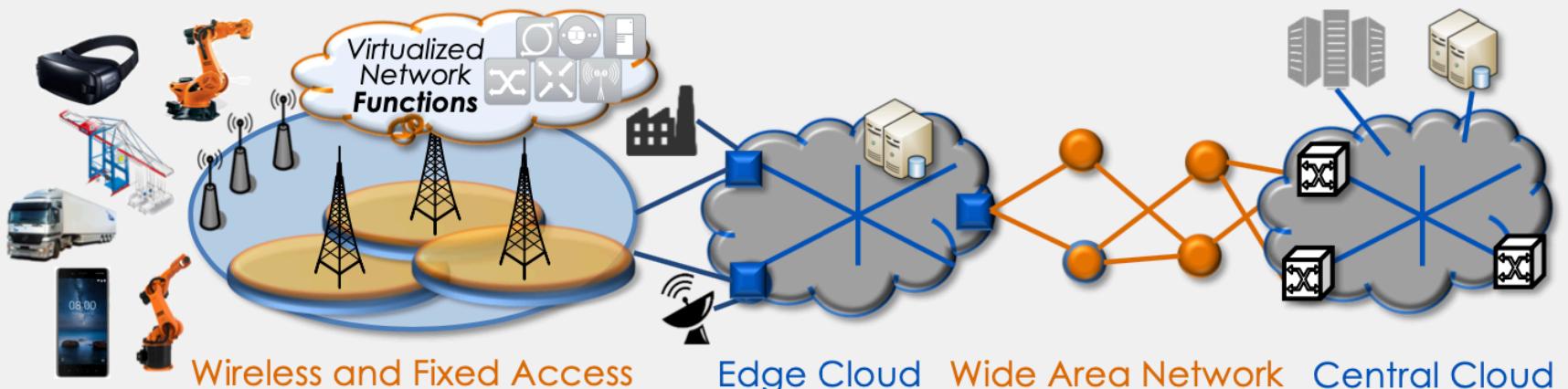
Cloud Mgmt.

Level 2:
Network
Slices

Industry Slice

Media & Entertainment Slice

Level 1:
Network
Resources
and
Functions



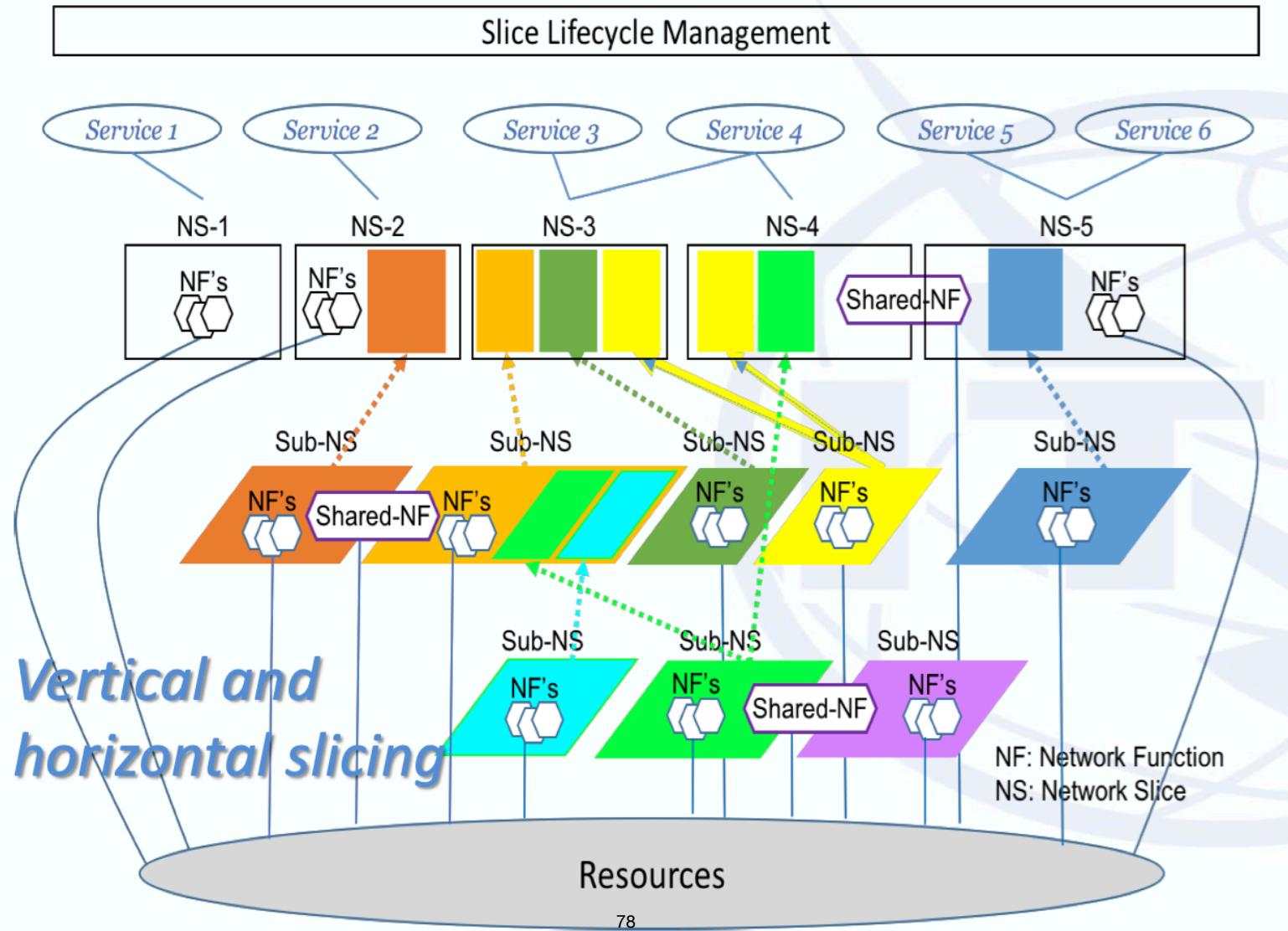
(Radio) Access Network (RAN)

Core Network (CN)



From: 5G-MoNArch Project video <https://www.youtube.com/watch?v=y6b9FNniPuQ>

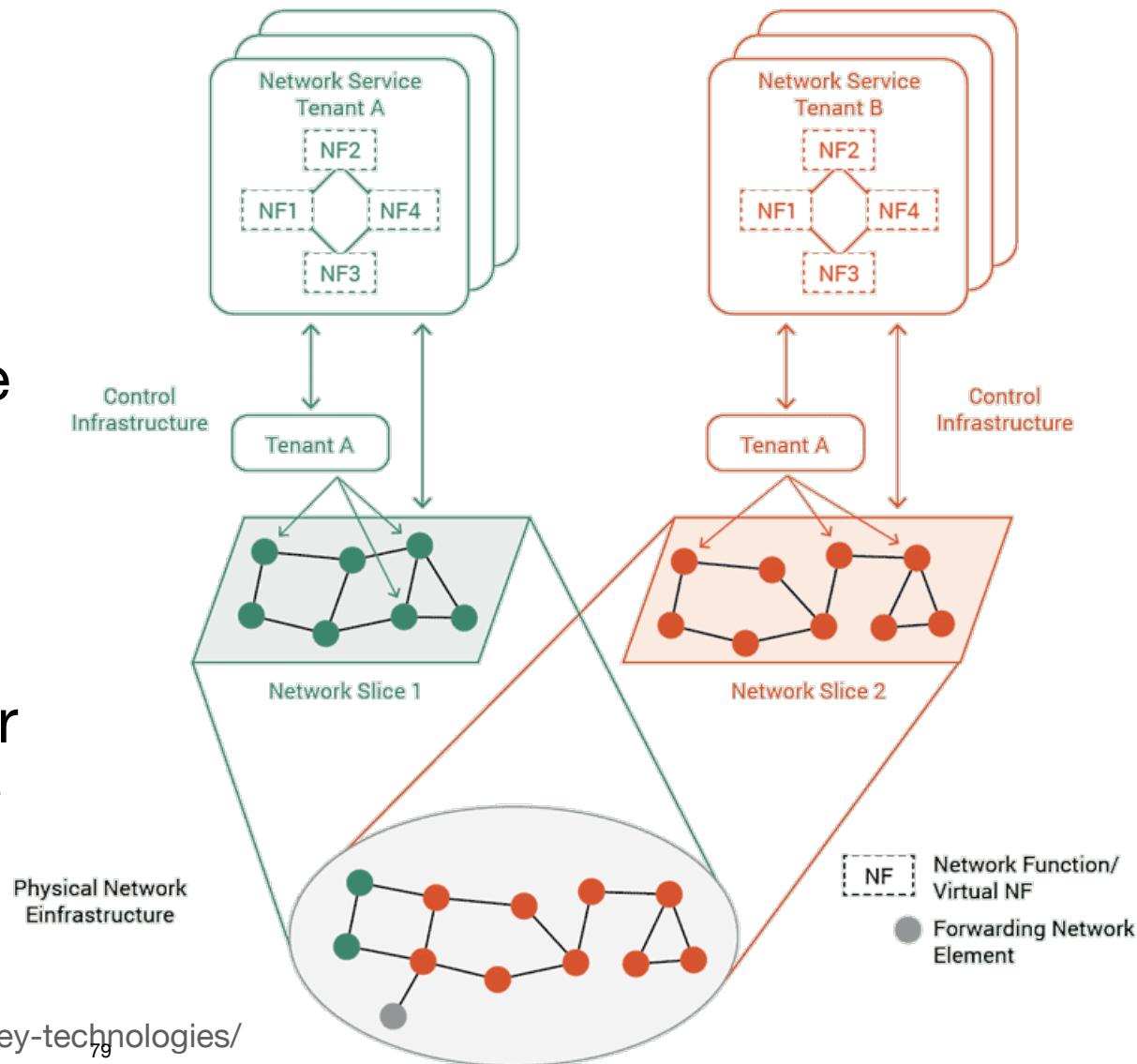
Network Slicing: Customized Support of Applications



• Network slices

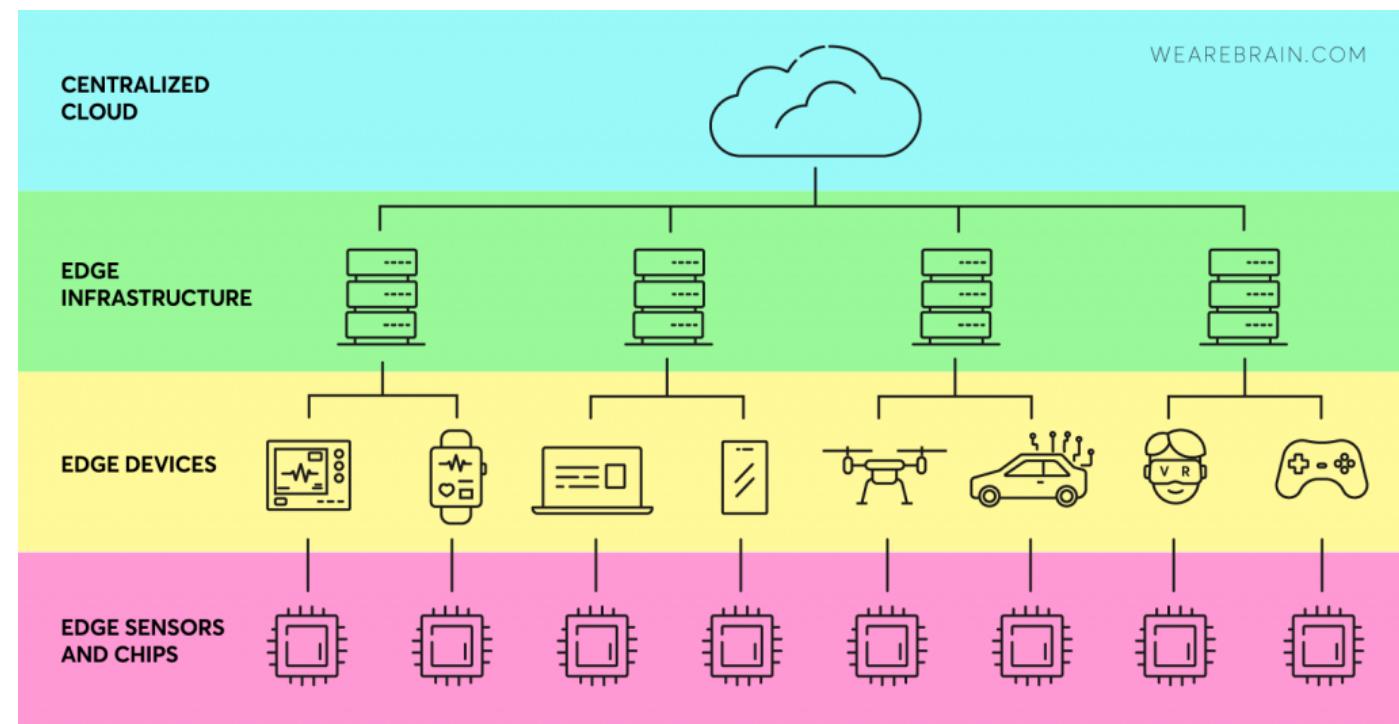
- Self-contained
- Mutually isolated
- Manageable & programmable
- Support for multi-service
- Support for multi-tenancy
 - Sharing the same system or program components while still ensuring data isolation between tenants

Multi-tenancy in Mobile Carrier Infrastructures



Edge Computing

- Facilitate data processing at or near the source of data generation
- Promise near real-time insights and facilitates localized actions



From Edge Sensors to Centralized Cloud

Centralized Cloud

Centralized data centers are farthest from the network edge. However, they offer a much greater density of compute, storage, and networking resources.

Edge Infrastructure

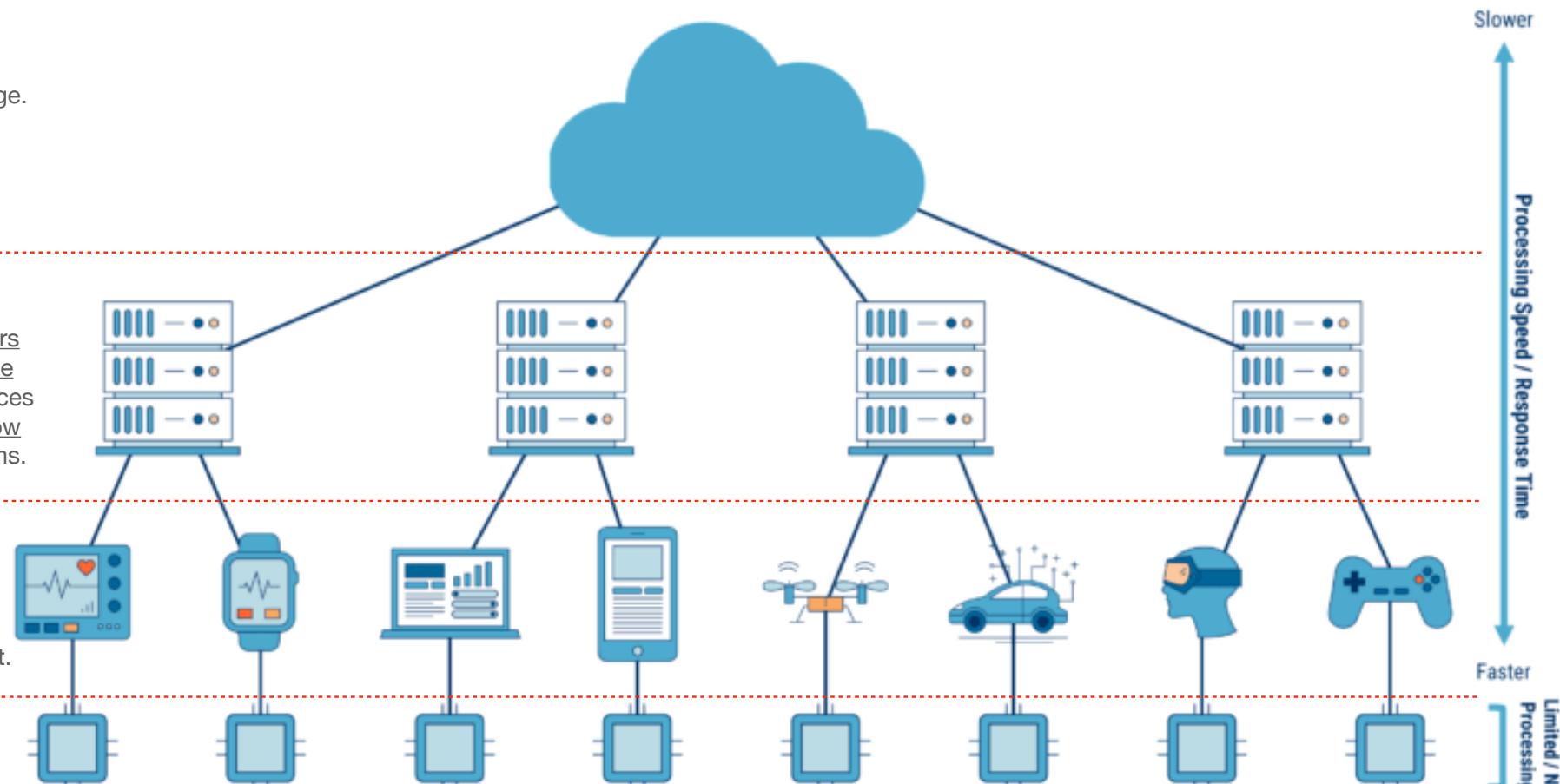
Small, distributed data centers that provide a resource-dense midpoint between edge devices and the centralized cloud. Low roundtrip latencies of 5 - 10ms.

Edge Devices

Real-time data processing within devices based on application needs. Processing limitations present.

Edge Sensors & Chips

Data collection & origination.



Cloud Computing vs Edge Computing

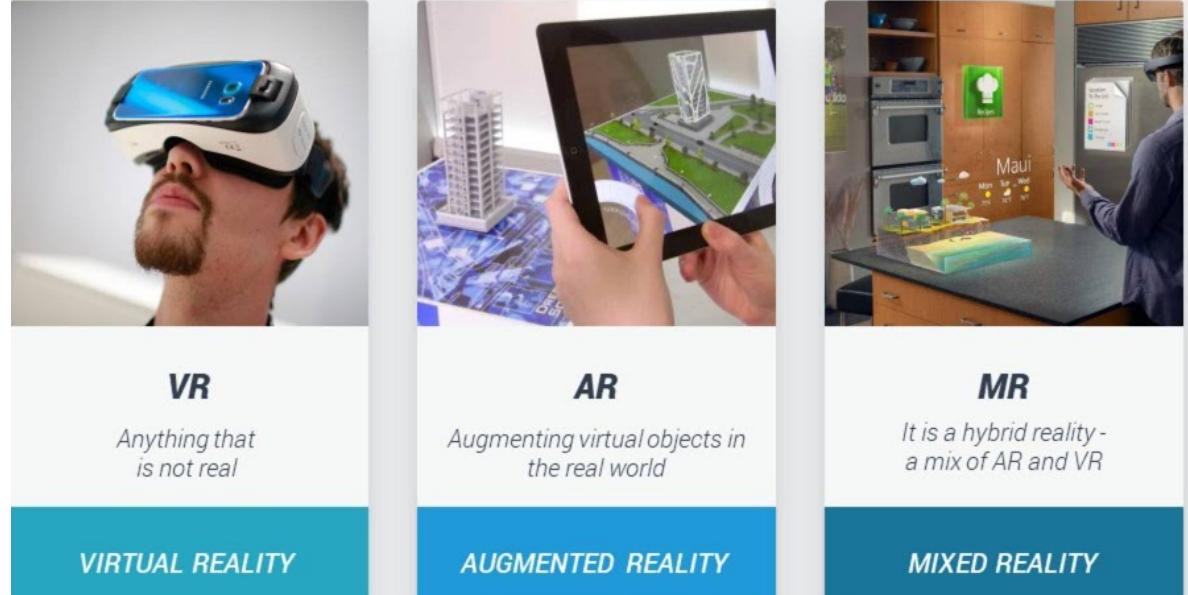
CLOUD COMPUTING	EDGE COMPUTING
LOCATION	
REMOTE - Storage, management and processing occurs on a <u>remote central</u> network server. The data is accessible over the Internet, away from the source.	NEAR-ACCESS - Data is processed physically <u>close</u> to or on the actual device, the data source, which is located at the edge of the network.
LATENCY	
HIGH - Frequent and high load data exchange puts strain on the network, resulting in <u>high latency</u> .	LOW - Requires little bandwidth as information is initially processed close to the data source.
CAPACITY	
HIGH - Can process <u>large</u> volumes of data and scale accordingly; cost is also determined by processing unit used.	LOW - Can only process so much data due to <u>limited</u> availability of resources. This is somewhat compensated by near-access communication with nodes.

CLOUD COMPUTING	EDGE COMPUTING
DISTRIBUTION	
CENTRALIZED - The cloud is a <u>Centrally</u> Managed System (CMS), which means it is controlled by a single entity.	DECENTRALIZED - Computations are performed at the <u>edge</u> of the network, often utilizing <u>distributed</u> nodes.
SECURITY	
HIGH - The virtual server is managed by one entity, which ensures <u>maximum</u> protection	MEDIUM - Distributed data means security can be more susceptible to <u>individual threats</u> and <u>unaccounted outside factors</u> .

CLOUD COMPUTING	EDGE COMPUTING
BENEFITS	
<ul style="list-style-type: none"> • Cost reduction • Scalability • Accessibility • Security 	<ul style="list-style-type: none"> • High speed and responsiveness • Low latency • Real-time results • Edge analytics
USE CASES	
<ul style="list-style-type: none"> • Inventory • BI and Big Data storage • Deep analysis • Rich data visualization • Dashboards • Reports • Back-end access 	<ul style="list-style-type: none"> • IoT (handheld devices, wearables) devices • IIoT (factory floor robots, digital signage at retail stores) devices • MRIs (Magnetic Resonance Imaging) • Traffic lights • Autonomous vehicles

Edge Computing Applications

- **Immersive experience**
 - AR/VR and mixed reality



- **Automotive & transportation**
 - Connected vehicles



- **Remote operation**
 - Factory, hospital

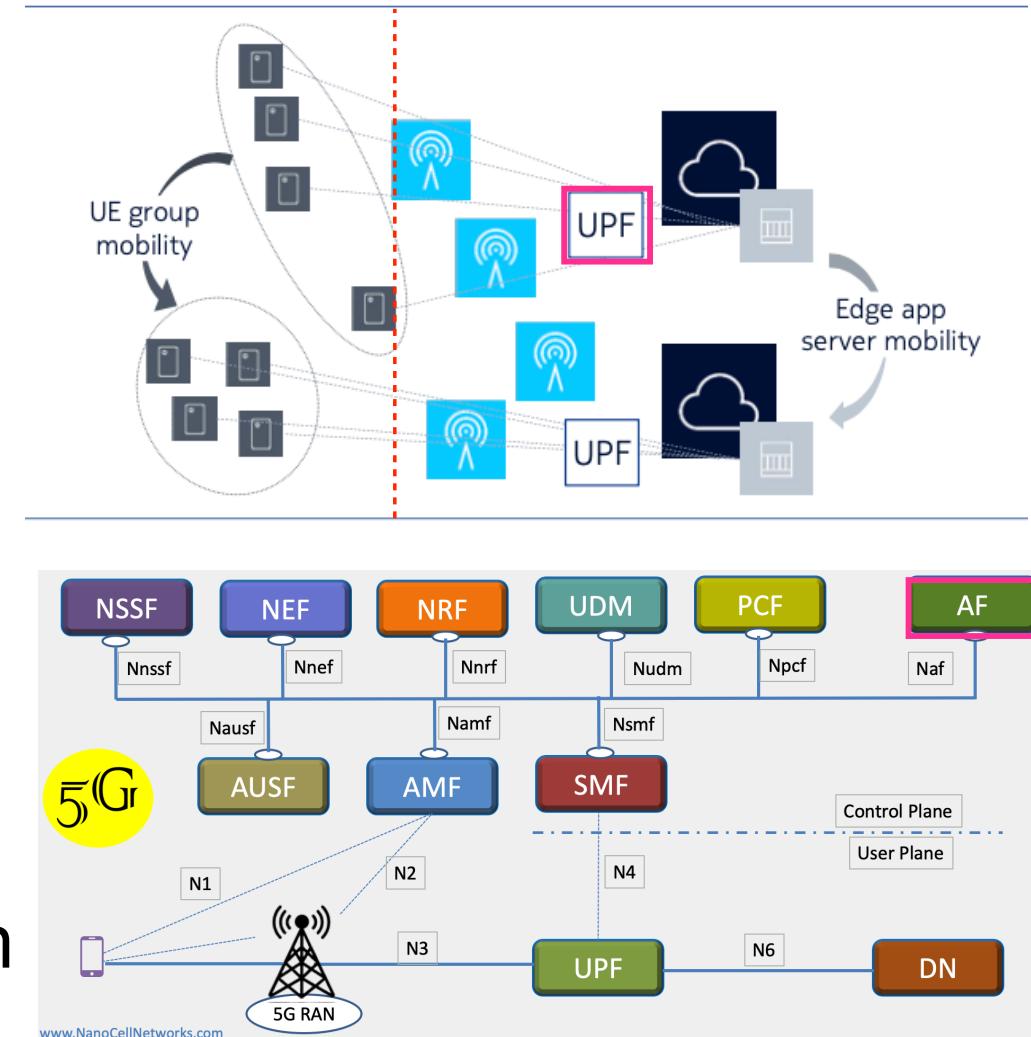


- **Intelligent automation**
 - Industrial and smart cities



Edge Computing Evolution

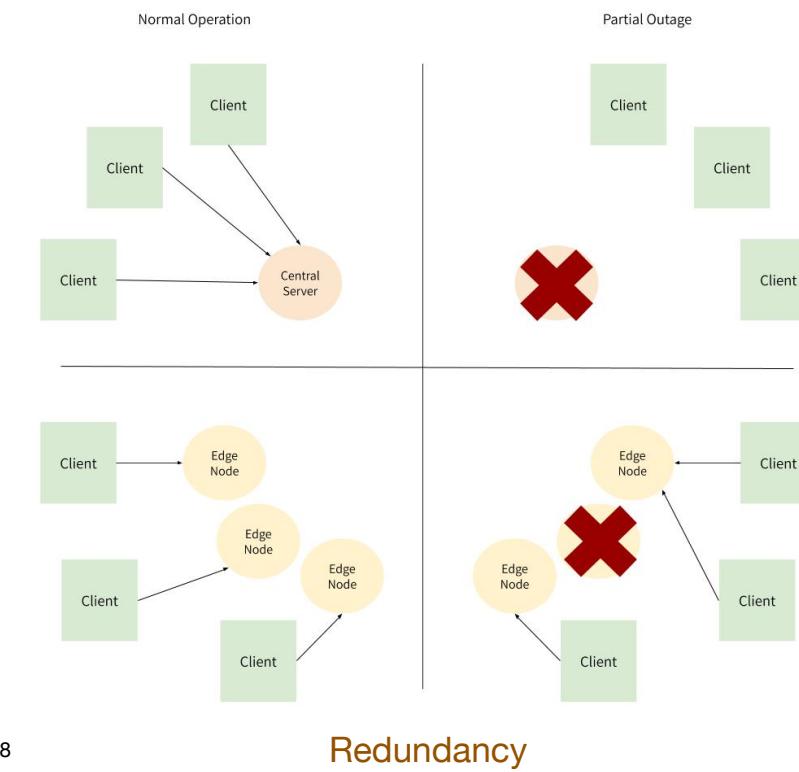
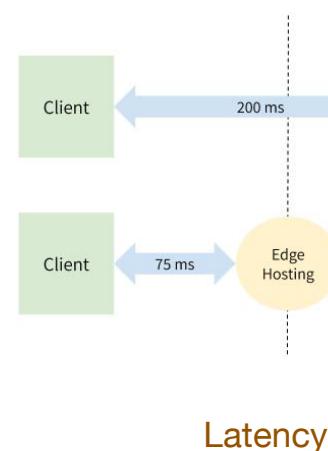
- **Rel-15:** Edge computing basic functionality
 - User Plane Function (UPF) offload capability
 - Application Function (AF) influence on traffic steering
- **Rel-17:** Dynamic insertion of offload capability depending on actual traffic



• Rel-18

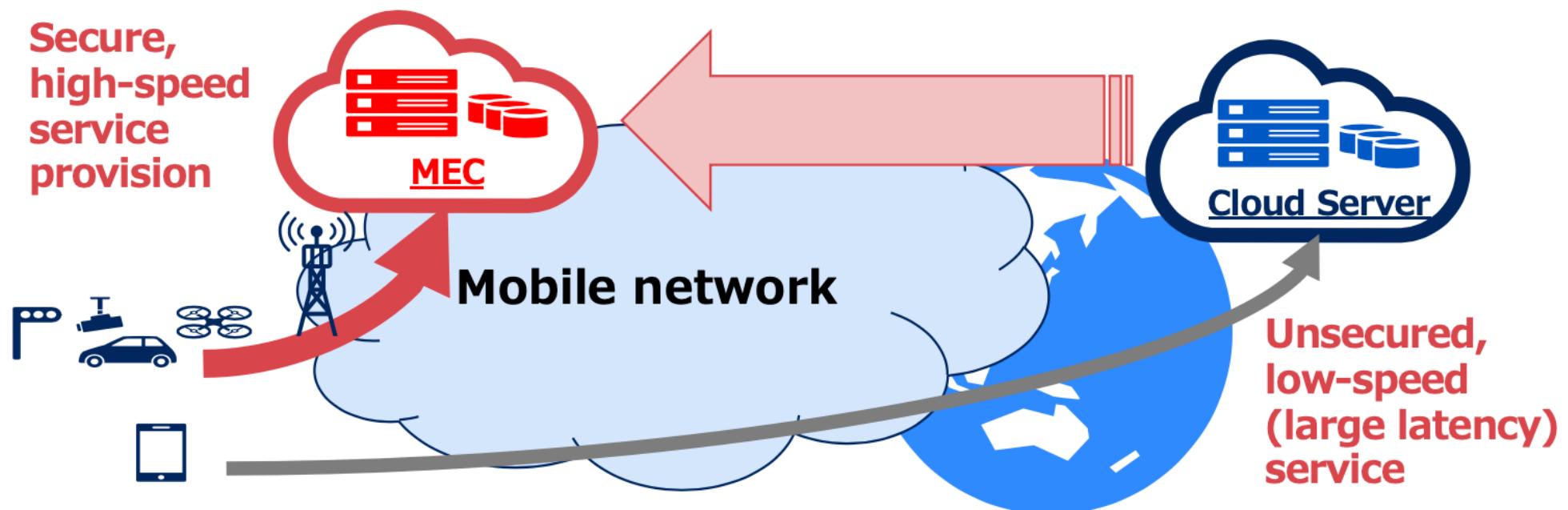
VPLMN: Visited Public Land Mobile Network

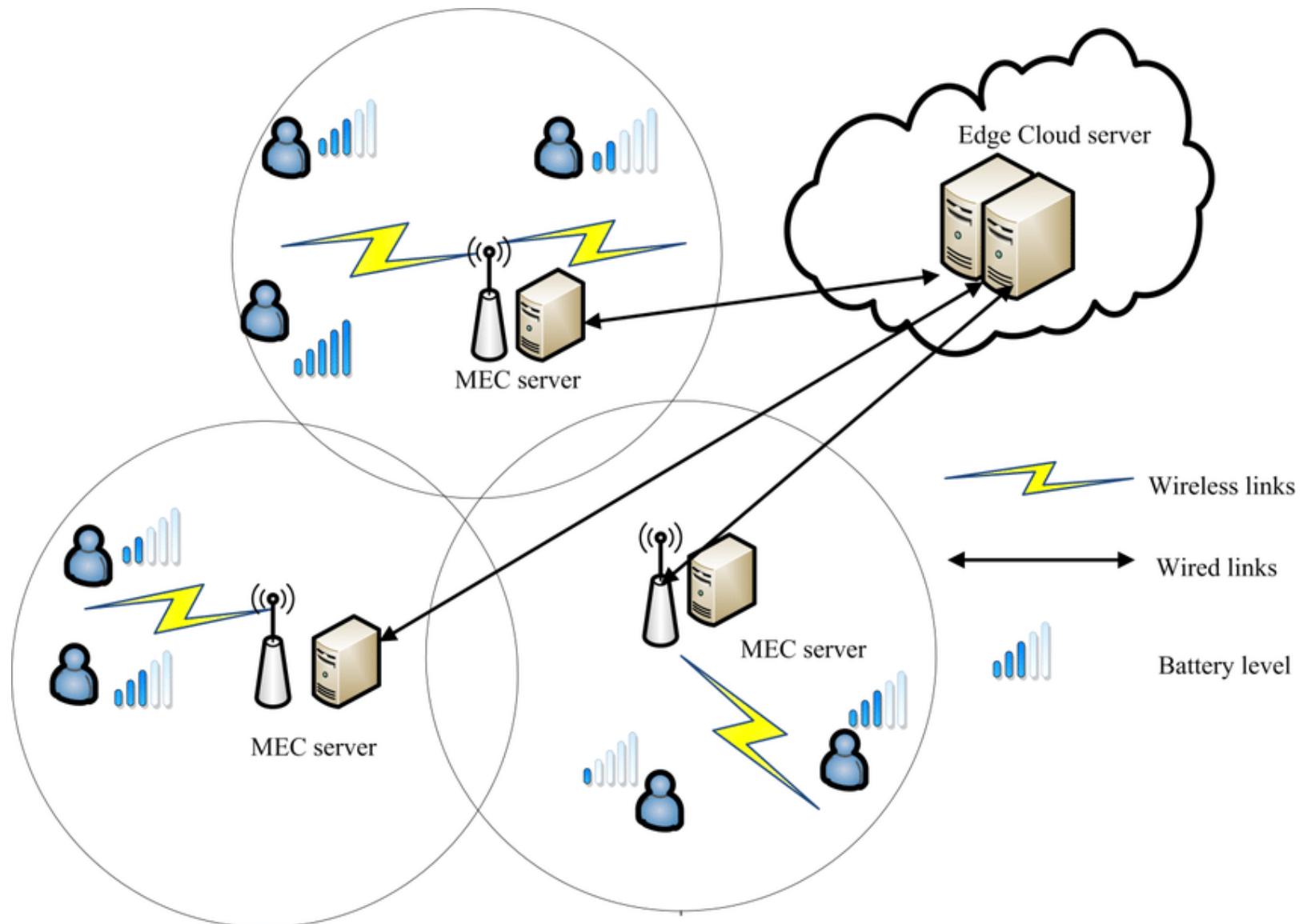
- Roaming support to access Edge Hosting Environment (EHE) in VPLMN
- Further enhancements for scenario where 5G Core and EHE are operated by different organizations

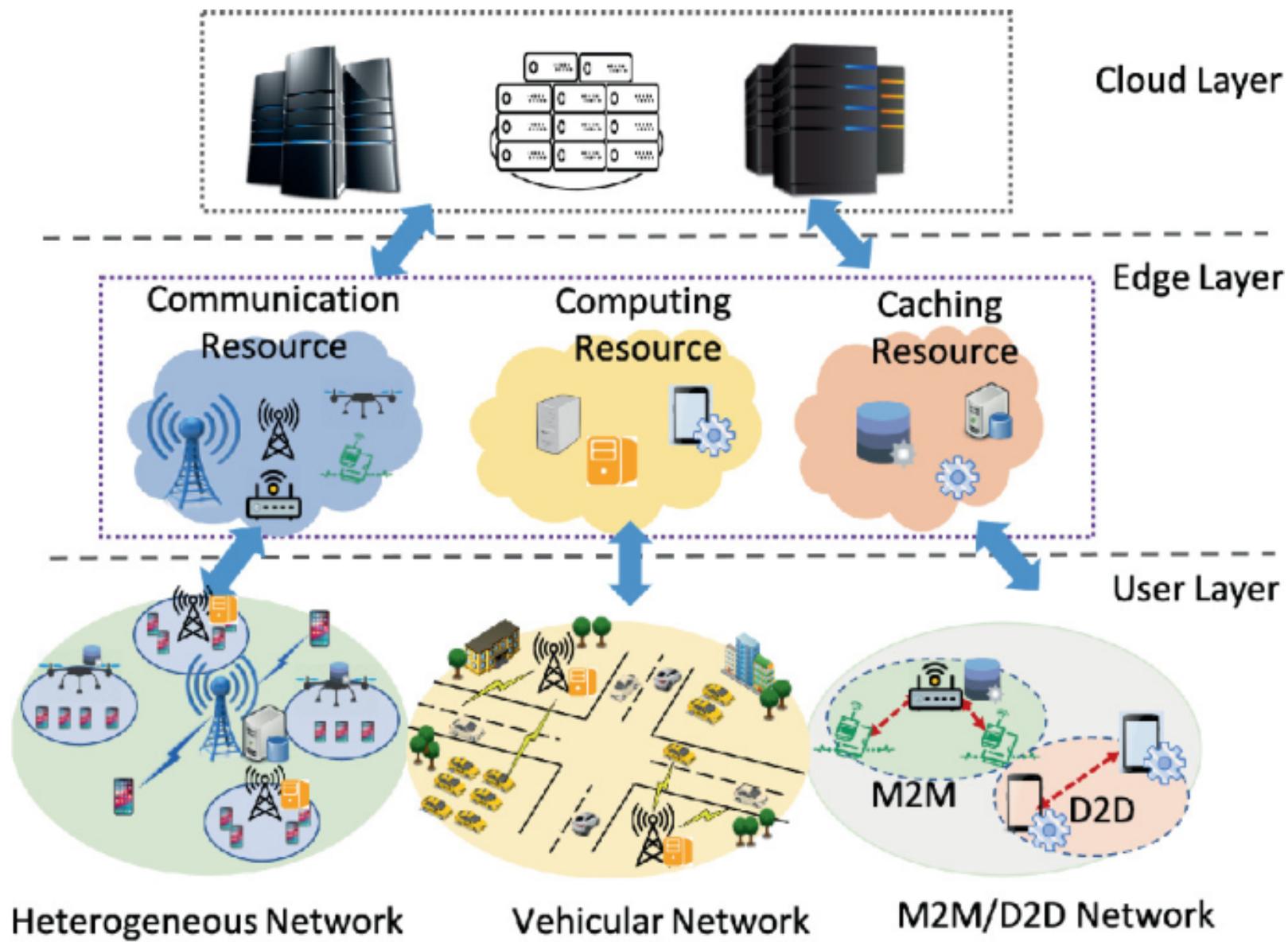


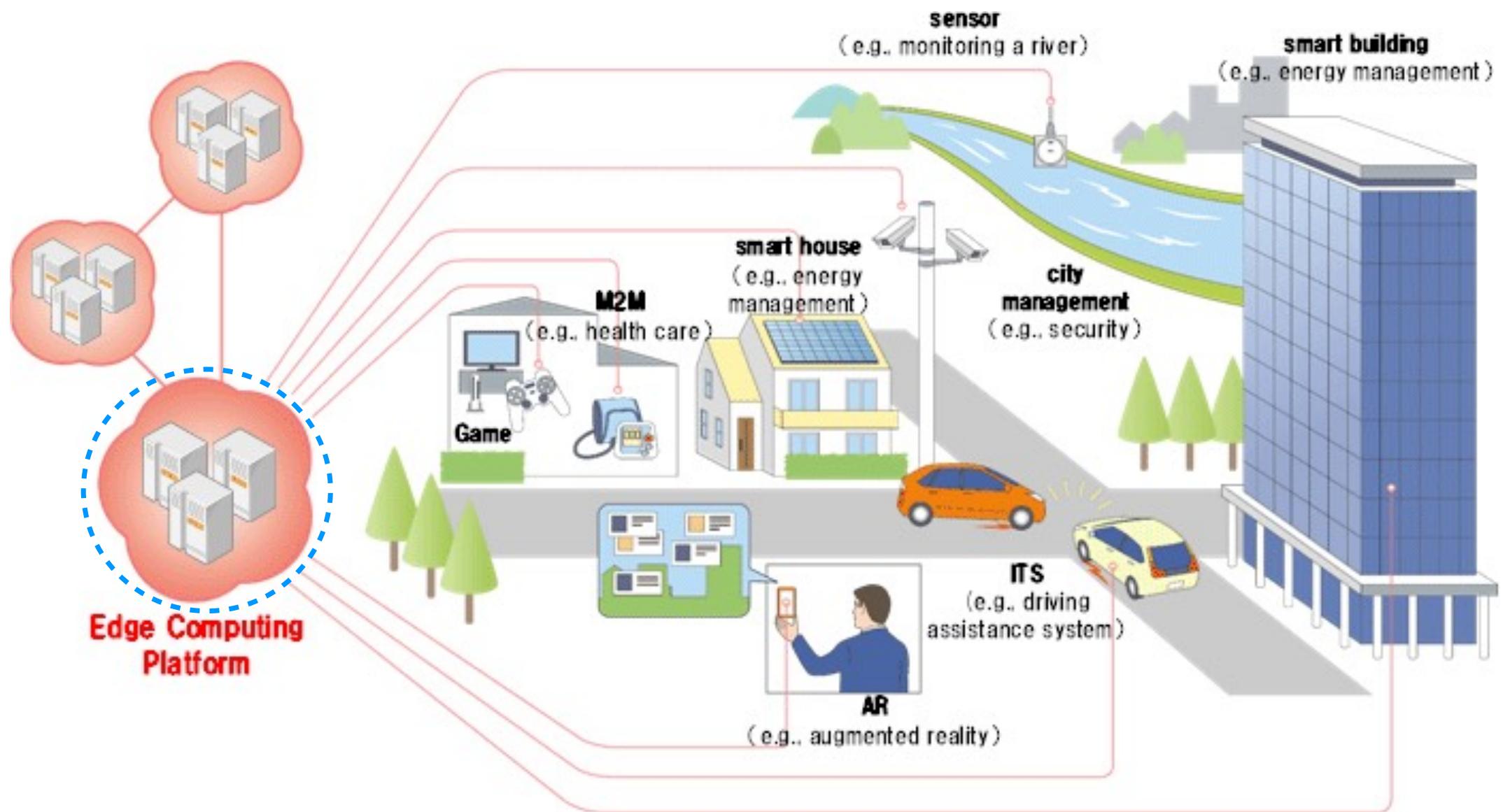
Mobile Edge Computing (MEC)

- Increases responsiveness from the edge
- Context related services, more information about the consumer (e.g., radio)

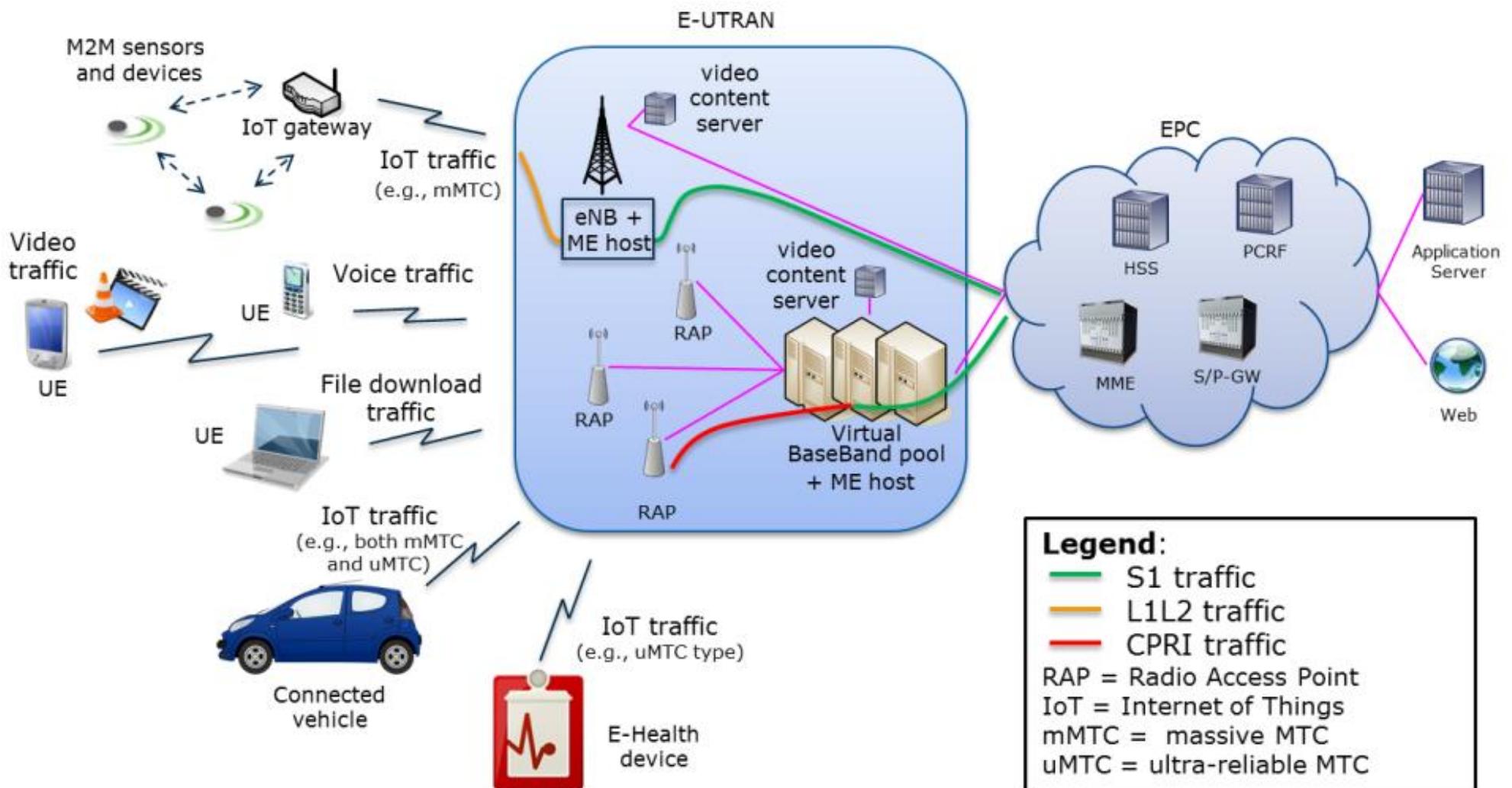




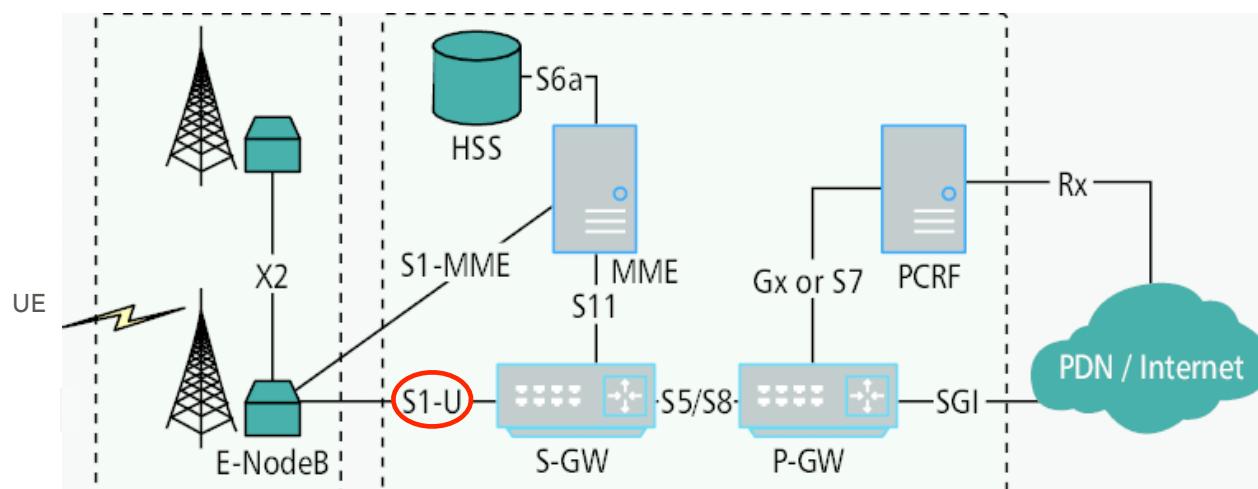
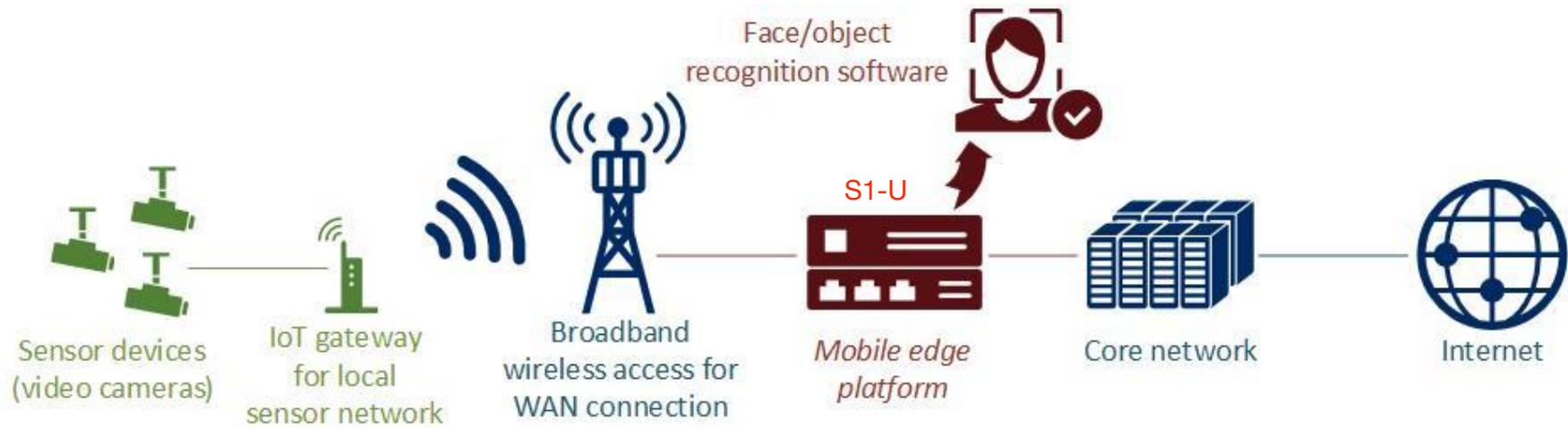




Mobile Edge Computing for 4G/5G Scenarios



MEC-based Video Surveillance (S1-U Option)



MEC-based Mobile IoT Scenario (SGi Option)

