Telcos Softwarization for the **5G**

IR.3503 - Virtual Infrastructure

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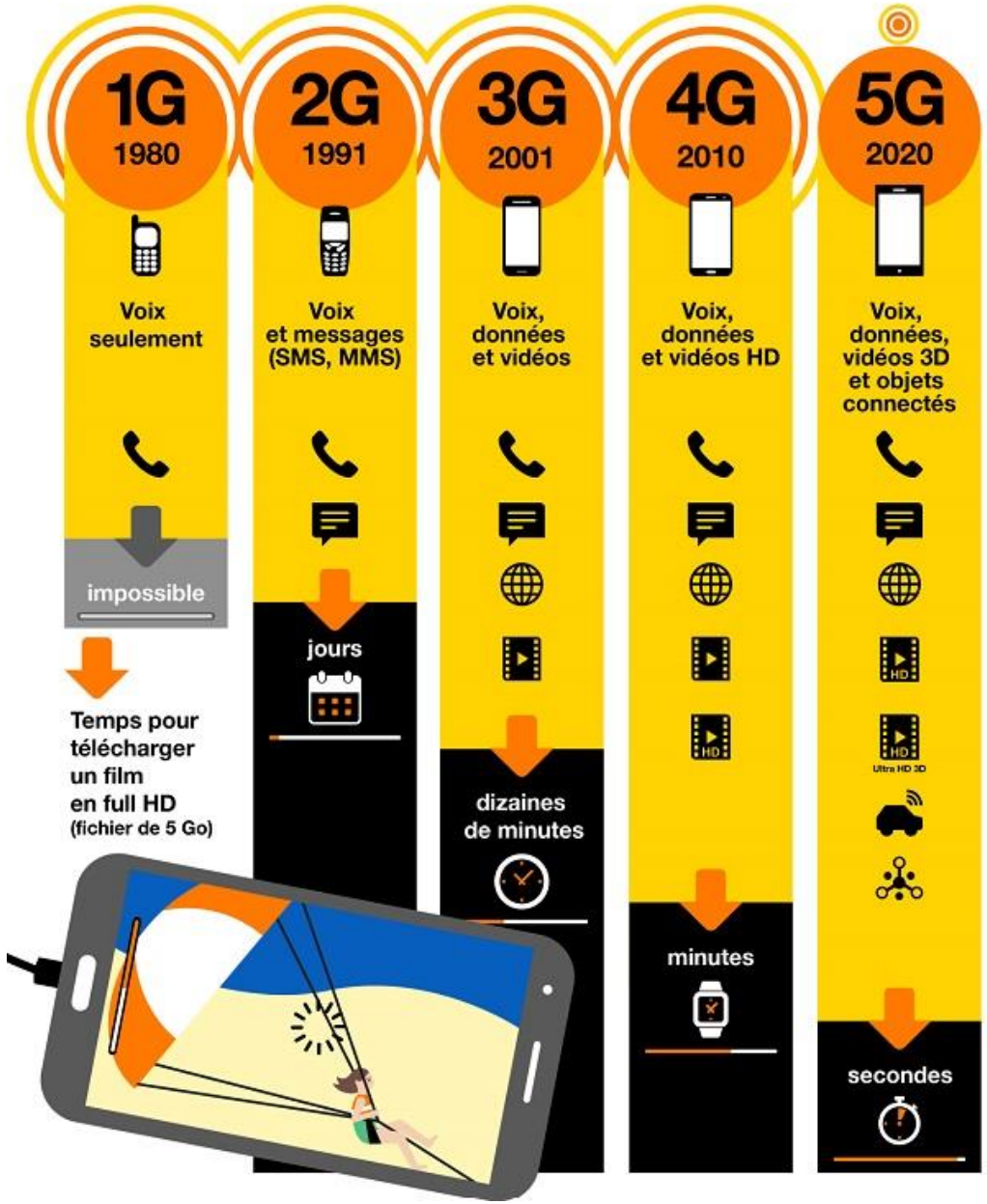
Agenda

1. 5G and Telcos Softwarization
2. Virtualization Concepts
3. Network Orchestration and Management
4. Network Function Virtualization (NFV)
5. Software Defined Networking (SDN)
5. Network Slicing
6. What about 6G?
7. Intent Based Management
8. Key Takeaways
9. References & Abbreviations

1.
5G & Telcos Softwarization

- What is 5G ?
- How 5G is different ?: main drivers and (business) use-cases
- The transition from 4G to 5G
- What does 5G CN look like ?
- What is Telcos Softwarization ?

1. 5G & Telcos Softwarization



1G (First Generation)

Technology: Analog
Speed: Around 2.4 kbps (kilobits per second)
Usage: used for voice calls, no data capabilities

2G (Second Generation)

- **Technology**: Digital (GSM)
- **Speed**: Up to 50-100 kbps
- **Usage**: Text messaging (SMS), Multimedia Messaging Service (MMS) and voice calls

3G (Third Generation)

- **Technology**: Digital (Universal Mobile Telecommunications System (UMTS))
- **Speed**: 200 kbps to 2Mbps
- **Usage**: Mobile internet browsing, Video calling ,Streaming audio and video, Online gaming

4G (Fourth Generation)

- **Technology**: LTE (Long-Term Evolution)
- **Speed**: 10-100 Mbps
- **Usage**: faster downloads/uploads, High-speed mobile internet, HD video streaming, and

5G (Fifth Generation)

- **Technology**: NR (New Radio)
- **Speed**: from 50 Mbps to 10 Gbps (gigabits per second)
- **Usage**: Ultra-fast internet, low-latency applications, enhanced mobile broadband, IoT (Internet of Things), and advanced applications like augmented reality (AR) and virtual reality (VR), Video 360

math

For a Game of Thrones Episode ~1,5 GB:

1G	2G	3G	4G	5G
No data	50 kbps	1 Mbps	100 Mbps	300 Mbps/10Gbps
No data	71 hours	3,58 hours	2,147 minutes	42, 94 seconds/1,2seconds

Key Takeaways:

- **1G**: Voice only, very slow.
- **2G**: Introduced digital communication, text messaging
- **3G**: Enhanced mobile internet and multimedia capabilities.
- **4G**: Significant speed improvements, enabling HD streaming and faster downloads.
- **5G**: Revolutionary speeds and low latency, supporting a wide range of new applications.

Standardization bodies:

Telecom standardization bodies are organizations that develop and promote technical standards for telecommunications.

These standards ensure interoperability, safety, and efficiency in communication systems.

Standardization bodies:

1.ITU (International Telecommunication Union): A UN agency that coordinates global telecommunication standards.
2.ETSI (European Telecommunications Standards Institute): Focuses on standardization in Europe, covering various telecom sectors.
3.3GPP (3rd Generation Partnership Project): Develops standards for mobile telecommunications, including 4G and 5G.
4.IEEE (Institute of Electrical and Electronics Engineers): Known for standards in networking and telecommunications, such as Wi-Fi.
5.IETF (Internet Engineering Task Force): Develops standards for the internet, including protocols like TCP/IP.
6.ISO (International Organization for Standardization): addresses telecom standards.

Standardization bodies:

3GPP (3rd Generation Partnership Project):

- **Focus:** Development of global mobile communication standards.
- **Scope:** Covers all generations of mobile technology (2G, 3G, 4G, 5G).
- **Function:** Produces technical specifications and reports for mobile networks.
- **Membership:** Comprises various stakeholders, including telecom operators, manufacturers, and research institutions.

Standardization bodies:

5GPPP (5G Infrastructure Public Private Partnership)

- **Focus**: Promotion and development of 5G technologies and infrastructure.
- **Scope**: Specifically targets 5G and its applications.
- **Function**: A public-private partnership aimed at fostering research and innovation in 5G.
- **Membership**: Involves industry players, academia, and public authorities, primarily in Europe.

Standardization bodies:

TMForum (TeleManagement Forum)

- **Focus**: Digital transformation and operational efficiency in telecom and digital services.
- **Scope**: Covers a wide range of topics, including service management, business processes, and IT systems.
- **Function**: Develops frameworks, best practices, and standards to help companies improve their operations and customer experiences.
- **Membership**: Comprises service providers, technology suppliers, and industry stakeholders.

Standardization bodies:

GSMA association, *Global System for Mobile Communications*

- **Focus**: Represents the interests of mobile operators worldwide.
- **Scope**: Covers mobile technology, including 2G, 3G, 4G, and 5G.
- **Function**: Advocates for the mobile industry, develops initiatives, and organizes events like Mobile World Congress.
- **Membership**: Comprises mobile operators, manufacturers, and related companies.

Standardization bodies:

NGMN (Next Generation Mobile Networks Alliance)

- Founded by world-leading Mobile Network Operators and open to all Partners in the mobile industry.
- It ensures that next generation network infrastructure, service platforms and devices will meet the requirements of operators
- It ensures user demand and expectations satisfaction

Standardization bodies:

CNCF (Cloud native Computing Foundation)

- **Focus**: Cloud-native technologies and practices.
- **Scope**: Supports projects that enable the development and management of scalable applications in cloud environments.
- **Function**: Hosts and fosters open-source projects like Kubernetes, Prometheus, and Envoy, providing resources and community support.
- **Membership**: Includes a wide range of stakeholders, from cloud providers to enterprises and developers.

In the end of this course you will be able to answer this questions:

What is the difference between 4G and 5G?

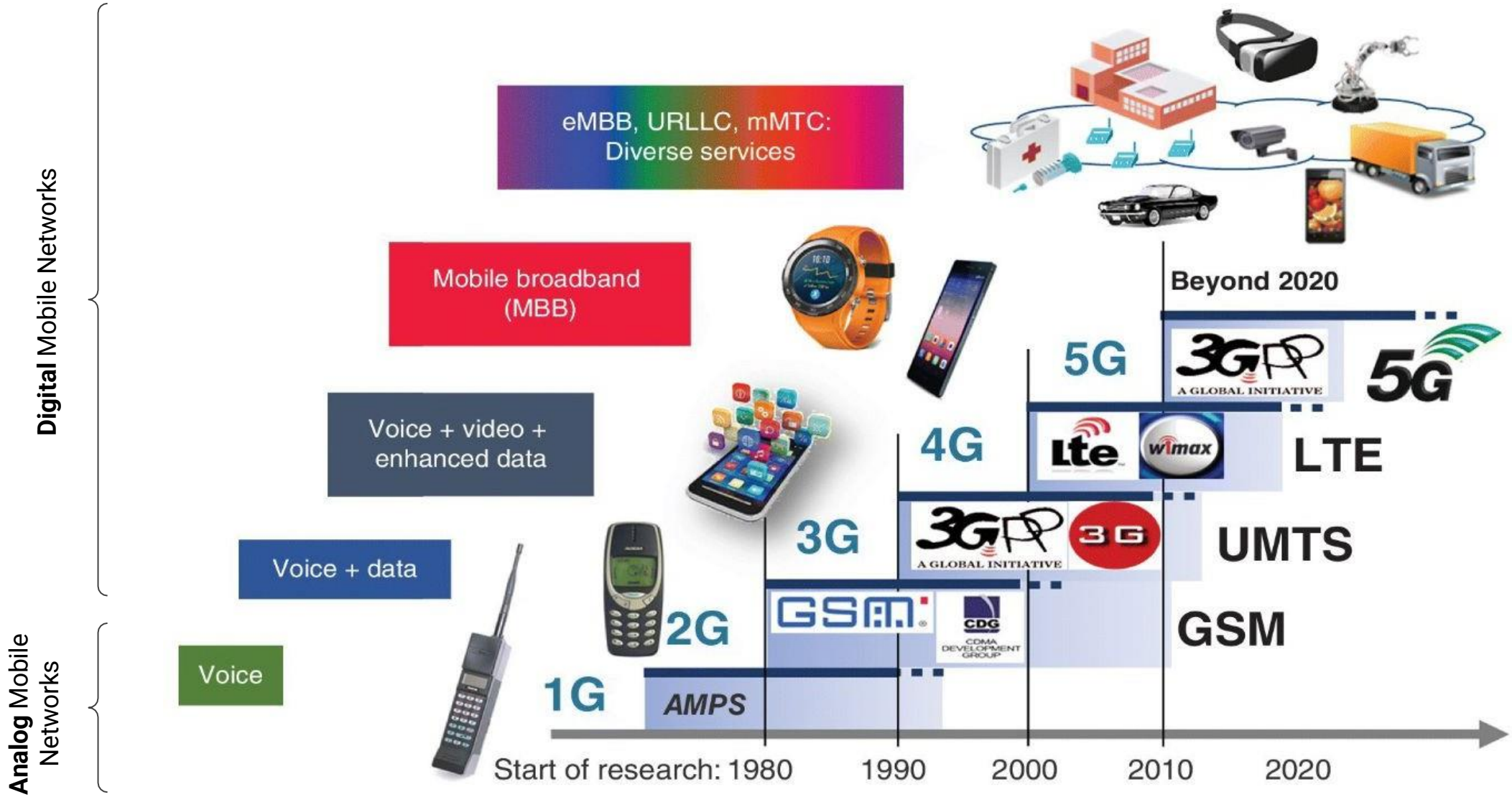
Provide 5G new applications and use cases?

Why do you call 5G architecture SBA?

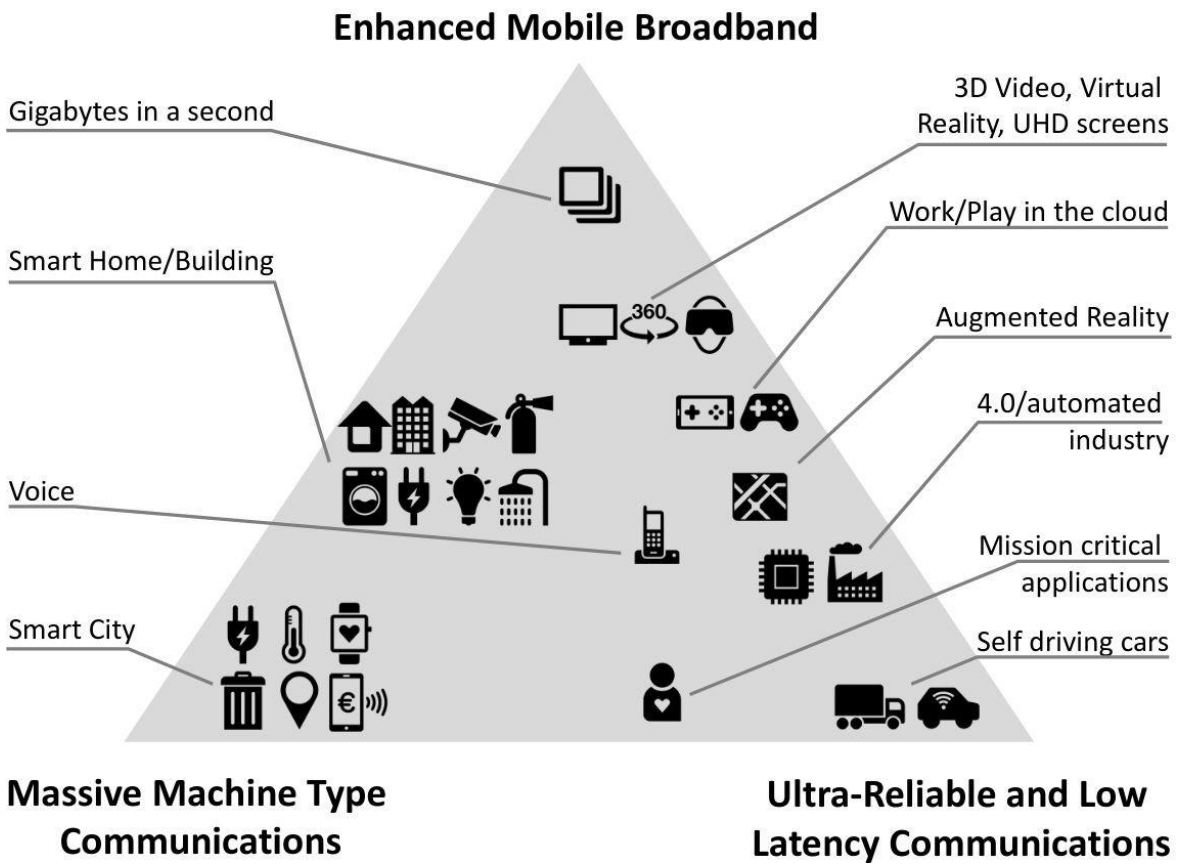
What is the difference between 5G SA and 5G NSA?

What is the aim of virtualization in 5G?

Main drivers behind cellular communications



Main drivers behind cellular communications



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Three Key Application Areas:

- **Enhanced Mobile Broadband (eMBB):** Better mobile phones and hot spots. High data rates, high user density. *Human centric communications*
- **Ultra-Reliable and Low-Latency Communications (URLLC):** Vehicle-to-Vehicle communication, mission critical communication, Industrial IoT. *Human and Machine centric communication*
- **Massive Machine Time Communications (mMTC):** Very large number of devices, low data rate, low power. IoT with long battery life time for smart cities. *Machine-centric communication*

Enhanced Mobile Broadband (eMBB)

- eMBB is the continuity of the multimedia-based services provided by the previous generations
- Main requirements concern extremely high peak data rates, large volumes of data traffic, support of high speed mobility and extensive coverage with user experience continuity.
- The success of eMBB also requires to meet challenging energy savings constraints.
- Major eMBB use cases are: mobile broadband access "everywhere", mobile broadband access in densely populated areas and high user mobility.

20 Gbps DL and 10 Gbps UL peak data rates

4 ms user-plane latency

50 Mbps Everywhere

500 km/h for high mobility

50% reduction on energy consumption

Ultra-Reliable and Low-Latency Communications (URLLC)

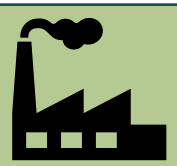
Low latency
1-20 ms

Mobility
300-500 jm/h

High reliability

High throughput
10-100Mbps

Automotive
- Remote driving, autonomous cars, platooning
- Assisted driving: see-through, lane-merge, road user protection



Industry 4.0
- Industrial control and automation, reconfigurable production lines
- Remote control for drones and robots

e-health and wellness
- Tele-diagnosis, tele-surgery and tele-rehabilitation
- Vital sign monitoring (telecare)

Media and entertainment
- Remote education and training
- immersive gaming. hologram

Massive Machine Time Communications (mMTC):

Density
1 000 000 device/km^2

• Smart Cities
IoT (Internet of Things): Facilitates the connection of millions of sensors and devices, improving resource management (water, energy, waste).

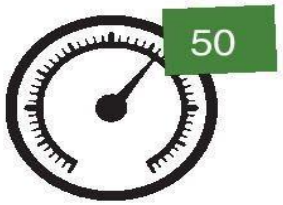
NGMN use case groups

Broadband access in dense areas

PERVASIVE VIDEO

Broadband access everywhere

50+ MBPS EVERYWHERE



Higher user mobility

HIGH SPEED TRAIN

Massive Internet of things

SENSOR NETWORKS

Extreme real-time communications

TACTILE INTERNET

Lifeline communications

NATURAL DISASTER

Ultra-reliable communications

E-HEALTH SERVICES

Broadcast-like services

BROADCAST SERVICES

NGMN use case groups

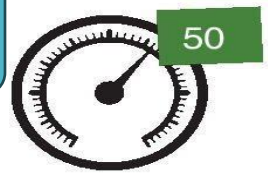
Broadband access in dense areas

PERVASIVE VIDEO

eMBB

Broadband access everywhere

50+ MBPS EVERYWHERE



eMBB

Higher user mobility

HIGH SPEED TRAIN

eMBB

Massive Internet of things

SENSOR NETWORKS

mMTC

Extreme real-time communications

TACTILE INTERNET

URLLC

Lifeline communications

NATURAL DISASTER

URLLC

Ultra-reliable communications

E-HEALTH SERVICES

URLLC

Broadcast-like services

BROADCAST SERVICES

eMBB

What 5G applications for this use cases?

eMBB

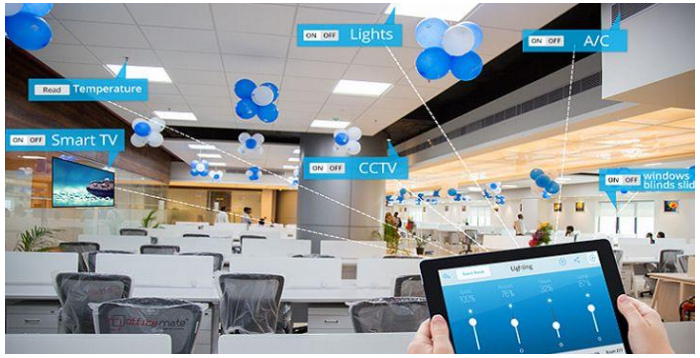
URLLC

mMTC

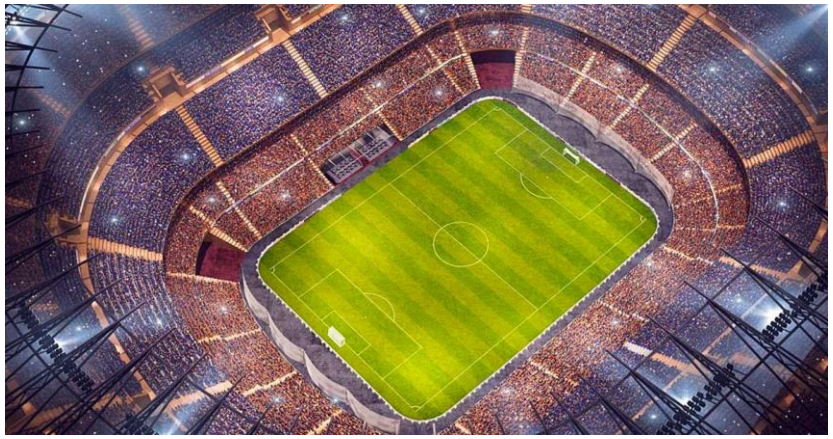
NGMN use case groups : Broadband Access in dense Areas

Pervasive Video

Smart Office



HD Video/Photo Sharing in Stadium/Open-Air Gathering



NGMN use case groups : Higher User Mobility

High Speed Train

Remote Computing

Moving Hot Spots

Aircrafts

NGMN use case groups : Massive Internet of Things (IoT)

Smart Wearables (clothes)

Sensor Networks

Mobile Video Surveillance

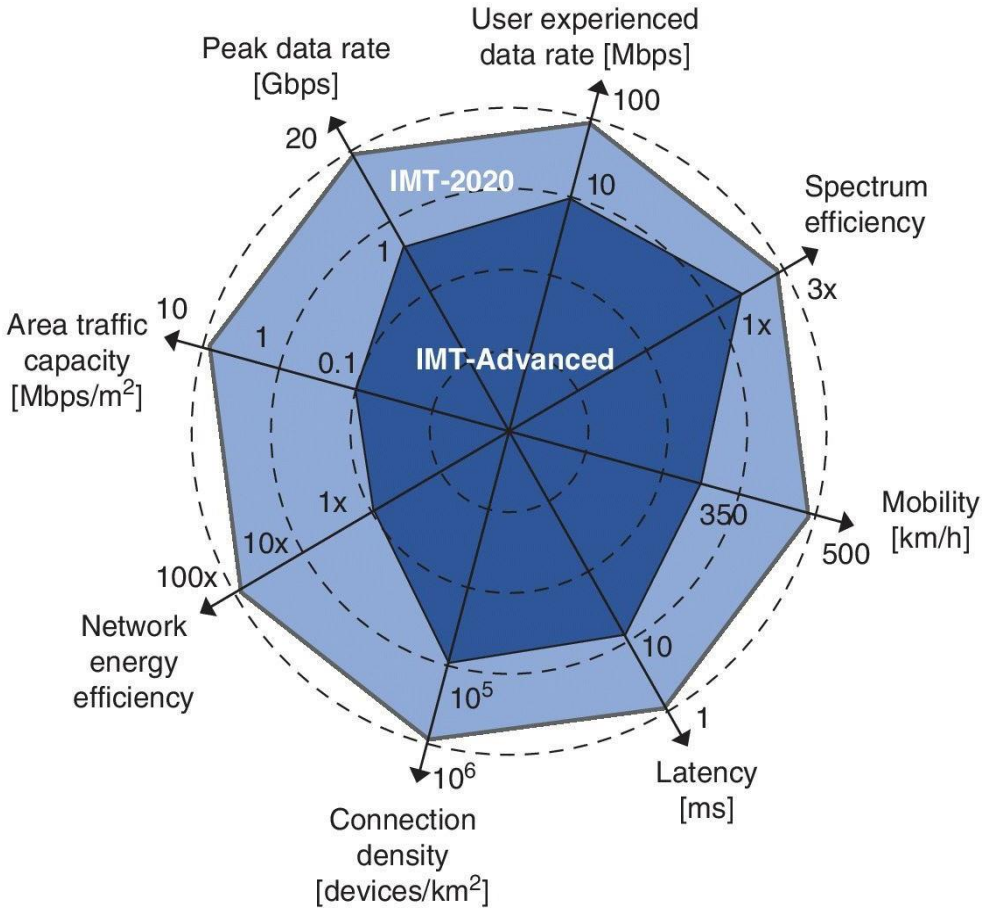
NGMN use case groups : Ultra-reliable Communications

Automated Traffic Control and Driving

Collaborative Robots: A Control Network for Robots

eHealth: Extreme Life Critical

IMT-2020 (5G) vs. IMT-Advanced (4G) [28]



Downlink metrics

- **Peak Data Rate**: maximum rate per user under ideal conditions. 10 Gbps for mobiles, 20 Gbps under certain conditions.
- **User experienced Data Rate**: 95% Rate across the coverage area per user. 100 Mbps in urban/suburban areas. 1 Gbps hotspot.
- **Spectrum Efficiency**: Throughput per Hz per cell
- **Mobility**: Max speed at which seamless handover and QoS is guaranteed
- **Latency**: Radio contribution to latency between send and receive
- **Connection Density**: Devices per km2
- **Network Energy Efficiency**: Network bits per Joule, User bits per Joule
- **Area Traffic Capacity**: Throughput per m2

Core Networks Evolution from 4G to 5G

UE (User Equipement): Smartphones, tablets or IOT devices

Core Networks Evolution from 4G to 5G

- **USER PLANE**: Refers to the part of the network that carries user data traffic
- **Control PLANE**: Manages signaling and control functions within the network.

Core Networks Evolution from 4G to 5G

gNB (Next Generation Node B)

- **Technology**: 5G
- **Function**: Connects user equipment (UE) to the 5G core network.
- **Features**: Supports advanced features like network slicing and ultra-reliable low-latency communication (URLLC).

eNB (Evolved Node B)

- **Technology**: 4G LTE
- **Function**: Connects user equipment (UE) to the 4G core network.
- **Features**: Provides high-speed data and voice services

Core Networks Evolution from 4G to 5G

Gateways:

SGW (Serving Gateway)

- **Network**: 4G
- **Function**: Acts as a data router and forwards user data packets between the eNodeB (base station) and the PGW.
- **Role**: Handles mobility and session management.

PGW (Packet Gateway)

- **Network**: 4G
- **Function**: Connects the mobile network to external IP networks (like the internet).
- **Role**: Manages IP address allocation, QoS, and billing.

UPF (User Plane Function)

- **Network**: 5G
- **Function**: Replaces the SGW and PGW in the 5G architecture.
- **Role**: Handles user data traffic and connects to external networks, supporting advanced features like network slicing.

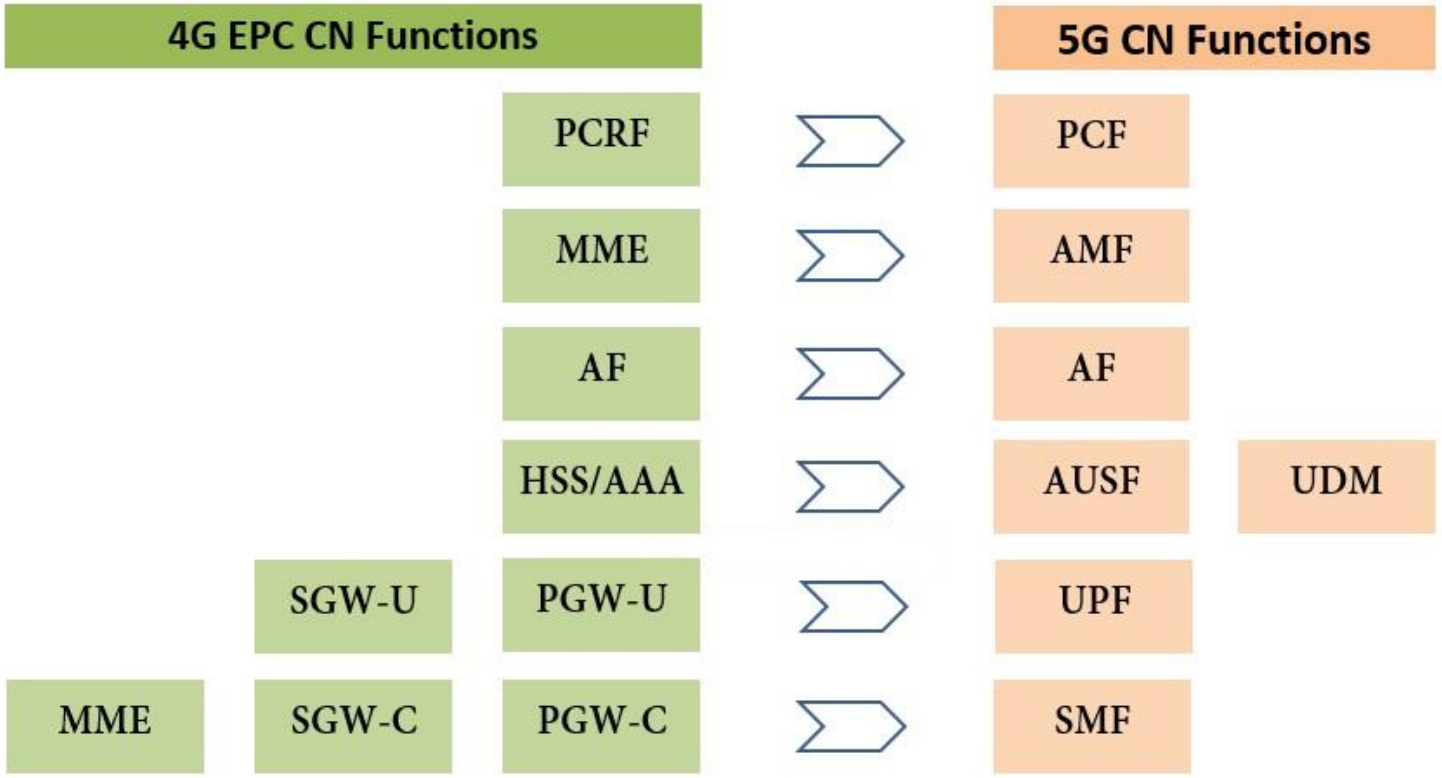
Core Networks Evolution from 4G to 5G

Mobility Management Entity (MME)/ Access and Mobility Management Function (AMF) :

- User Equipment (UE) Registration: Manages the registration of devices to the network.
- Mobility Management: Handles user mobility, including tracking and location updates as devices move.
- Session Management: Initiates and manages bearer paths for data sessions.
- Security: Manages security procedures, including encryption and authentication.

Core Networks Evolution from 4G to 5G

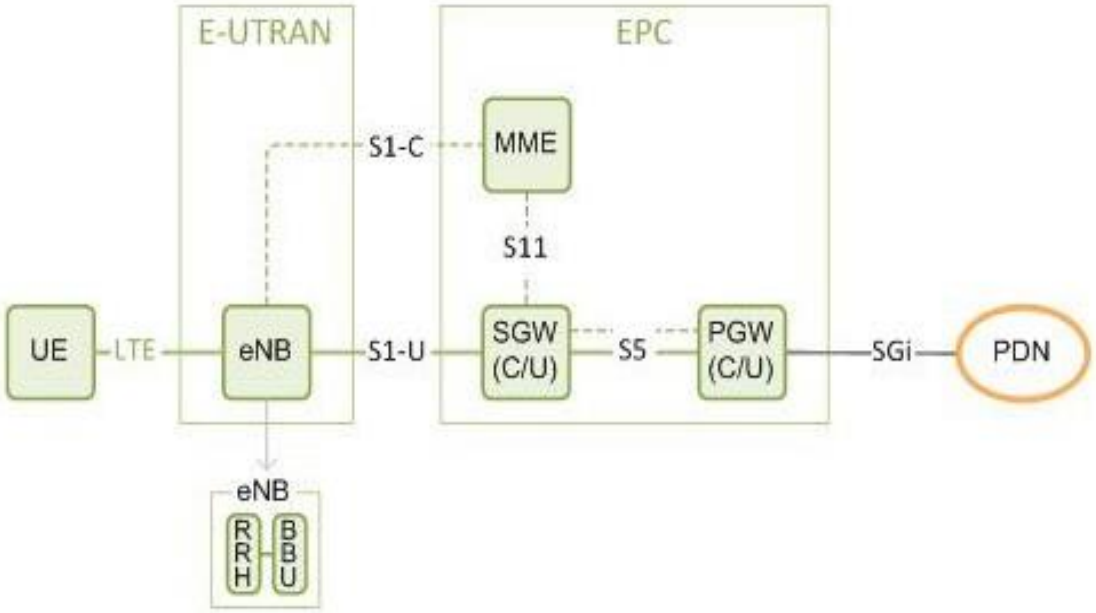
4G vs 5G Functions:



Core Networks Evolution from 4G to 5G

EPC without CUPS

Release 8 (3GPP TS 23.401)



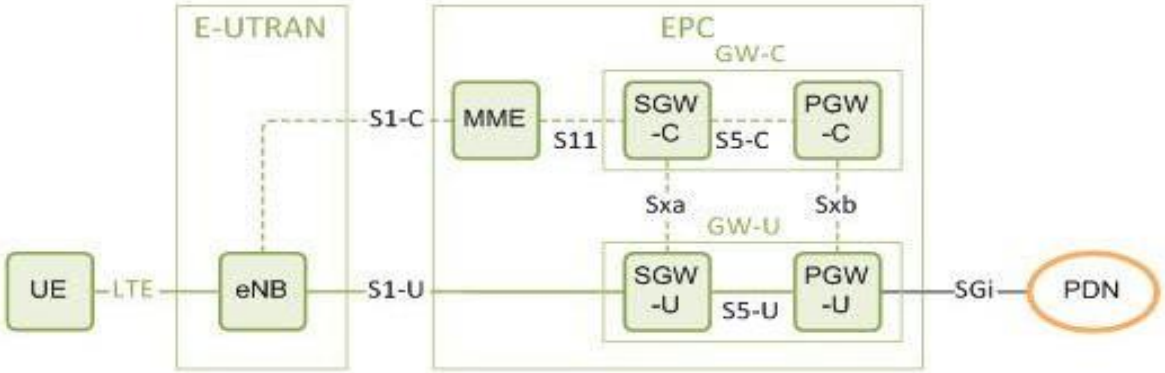
MME: Mobility Management Entity
SGW: Serving Gateway
PGW: PDN Gateway
PDN: Packet Data Network

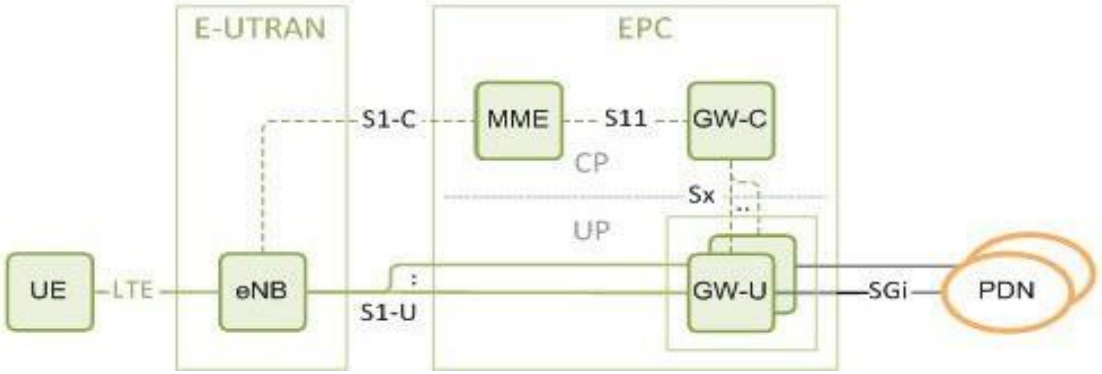
- GW (SGW/PGW) functions: vertically integrated control plane (CP) and user plane (UP) functions
- CP functions of GWs: processed separately for each GW
- Expensive customized and proprietary HW based architecture
- Limited scalability of GWs and high expansion costs as user traffic increases
- Centralized deployment of all GWs

Core Networks Evolution from 4G to 5G

EPC with CUPS

Release 14 (3GPP TS 23.401, TS 23.214)





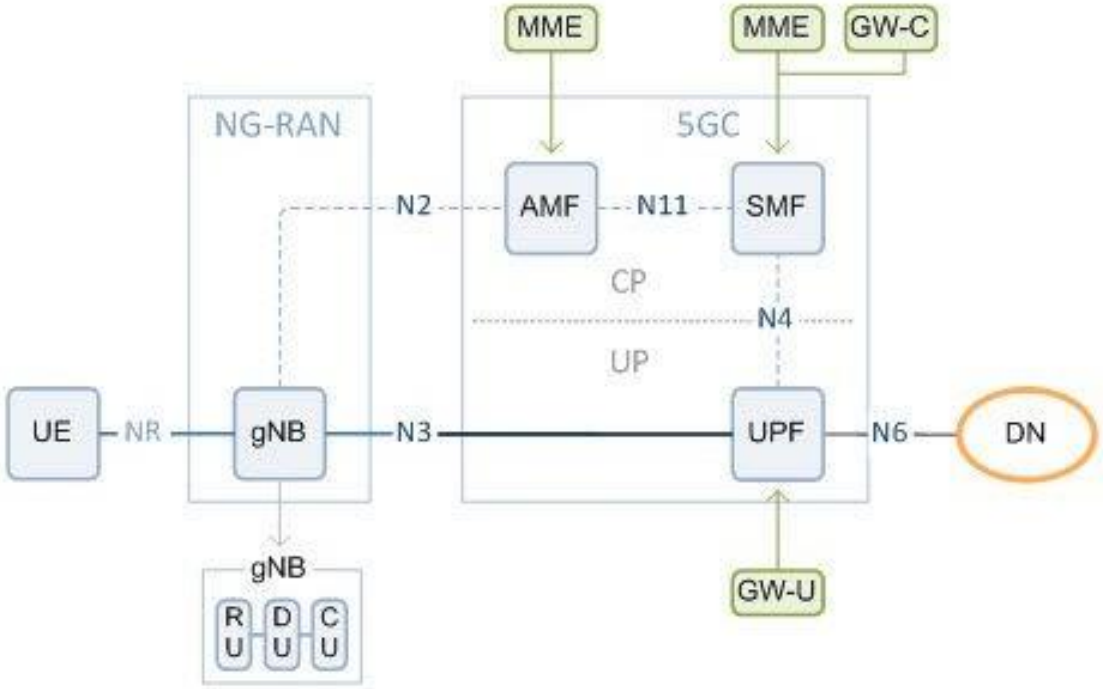
GW-C: Gateway Control Plane
GW-U: Gateway User Plane
BBU: Baseband Unit (or DU: Digital Unit)
RRH: Remote Radio Head (or RU: Radio Unit)

- GW functions: separated into CP and UP functions
- CP functions of GWs: processed centrally
- Inexpensive commodity hardware based architecture
- Scaling CP and UP functions independently (Enabling to add only GW-Us independently as user traffic increases)
- Enabling flexible deployment of GW-Us (closer to RAN) to reduce latency
- Independent evolution of CP and UP functions.

Core Networks Evolution from 4G to 5G

5G with CUPS: CUPS extended to RAN

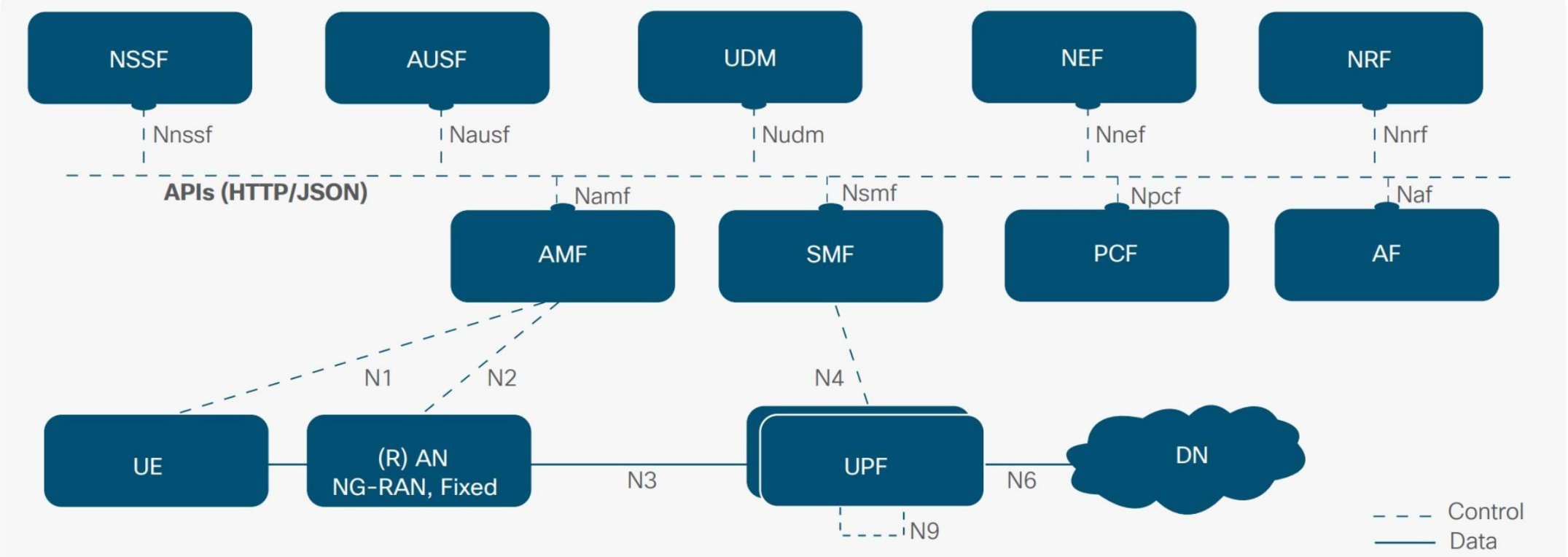
Release 15 (3GPP TS 23.501)



AMF: Access and Mobility Management Function
SMF: Session Management Function
UPF: User Plane Function
DN: Data Network
CU: Central Unit
DU: Distributed Unit
RU: Radio Unit

- Reconfiguring LTE network functions
- Support for native CUPS
- 'Virtualized NFs on commodity hardware' based architecture
- Distributed UPFs to edges to reduce latency and backhaul traffic
- Enabling standard-based MEC by supporting routing to local UPFs located at edge sites
- CUPS extended to RAN
- Enabling E2E network slicing by supporting independent paths for each service

5G system Service Based Architecture (SBA)



NSSF	Network Slice Selection Function
AUSF	Authentication Server Function
UDM	Unified Data Management Function
NEF	Network Exposure Function
NRF	Network Repository Function

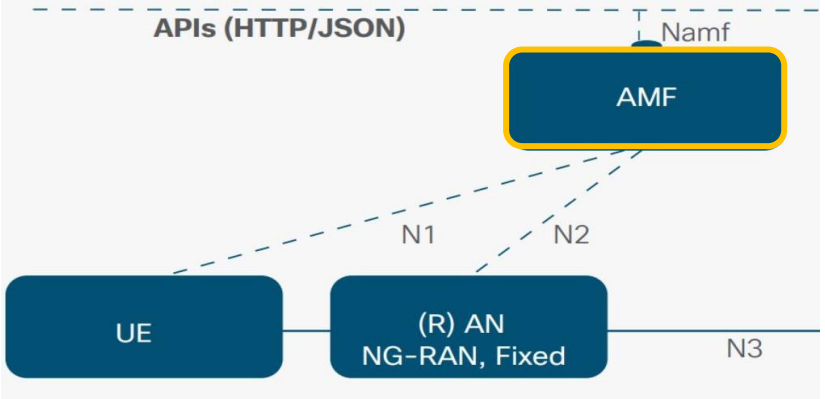
AMF	Access and Mobility Management Function
SMF	Session Management Function
PCF	Policy Control Function
AF	Application Function

UE	User Equipment
RAN	Radio Access Network
UPF	User Plane Function
DN	Data Network

5G system Service Based Architecture (SBA)

AMF: Access and Mobility Management Function

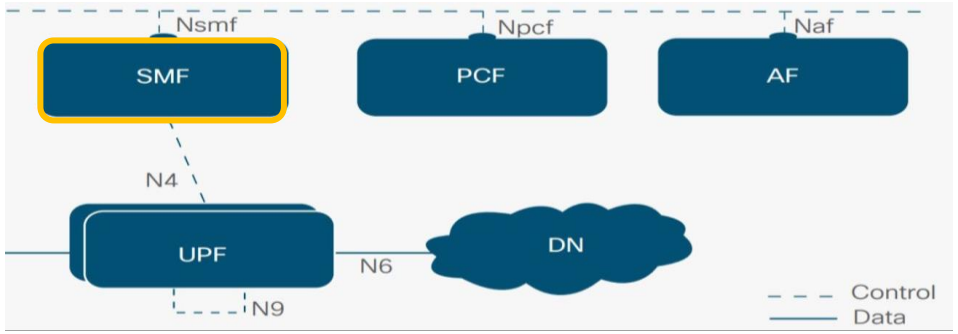
- Manages the registration of User Equipment (UE) in the network.
- Handles mobility procedures, including tracking and location updates as users move between different cells.
- Initiates and manages sessions for data transfer.
- Oversees user authentication and security procedures,
- Establishes and maintains connections between the UE and the network.



5G system Service Based Architecture (SBA)

SMF: Session Management Function

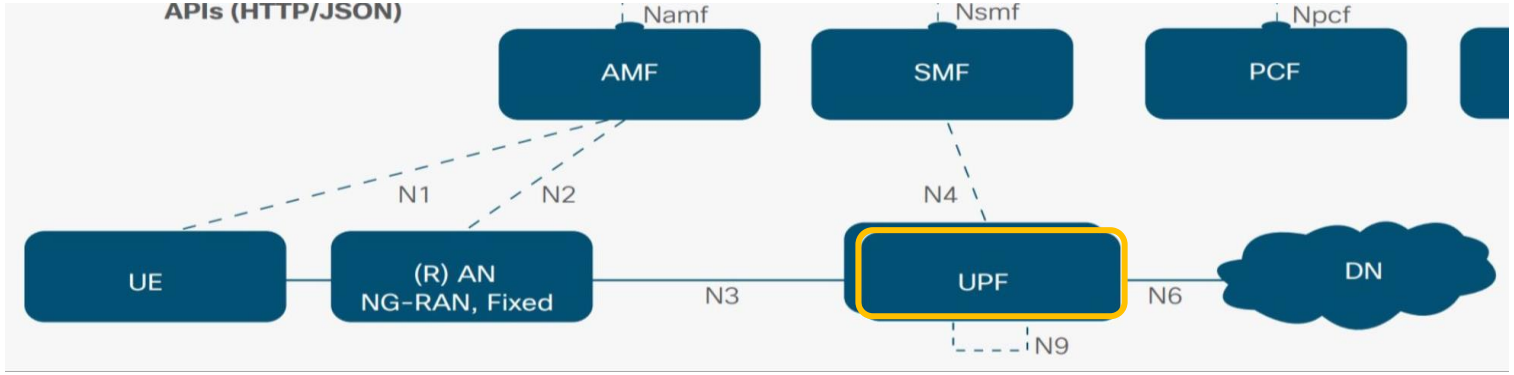
•Handles the establishment, modification, and termination of sessions for user data transfer.
•Initiates sessions based on user requests and network conditions.
• Configures QoS parameters for different sessions to ensure performance.
•Assigns IP addresses to User Equipment (UE) for data communication.
•Enforces policies related to data usage and resource allocation.



5G system Service Based Architecture (SBA)

UPF: User Plane Function

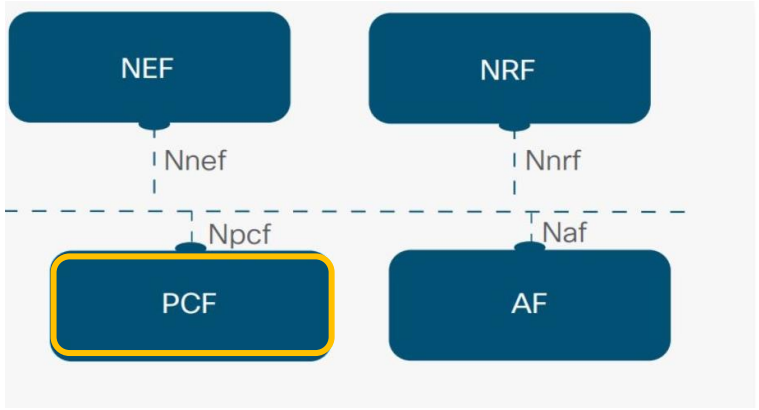
- Manages the forwarding of user data packets between User Equipment (UE) and external networks.
- SMF works closely with the User Plane Function (UPF) to manage data paths.
- Efficiently routes user data traffic.
- Implements QoS policies to ensure performance standards for different types of traffic.
- Balances load and optimizes data flow to prevent congestion.
- Establishes and maintains bearers for user data sessions.



5G system Service Based Architecture (SBA)

PCF: Policy Control Function

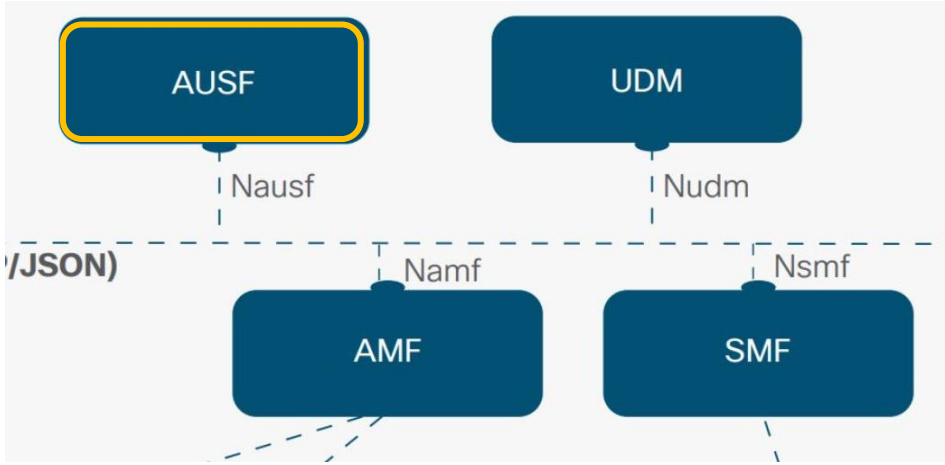
- Oversees the creation and enforcement of policies for network resource usage.
- Defines and manages Quality of Service (QoS) policies for different types of traffic.
- Implements policies related to billing and charging for data usage.
- Manages user access to network resources based on predefined policies.
- Allows for real-time adjustments to policies based on network conditions and user behavior.



5G system Service Based Architecture (SBA)

AUSF: Authentication Server Function

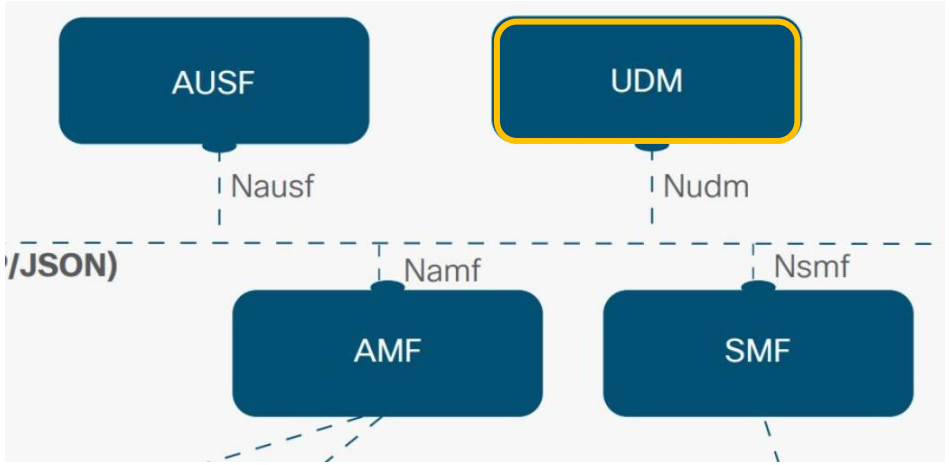
- Responsible for authenticating User Equipment (UE) to ensure secure access to the network.
- Works in conjunction with the Unified Data Management (UDM) and Access and Mobility Management Function (AMF).
- Executes authentication processes using various methods, such as SIM-based or EAP (Extensible Authentication Protocol).
- Generates and manages cryptographic keys used for secure communication.
- Ensures the integrity and confidentiality of user data during authentication



5G system Service Based Architecture (SBA)

UDM: Unified Data Management

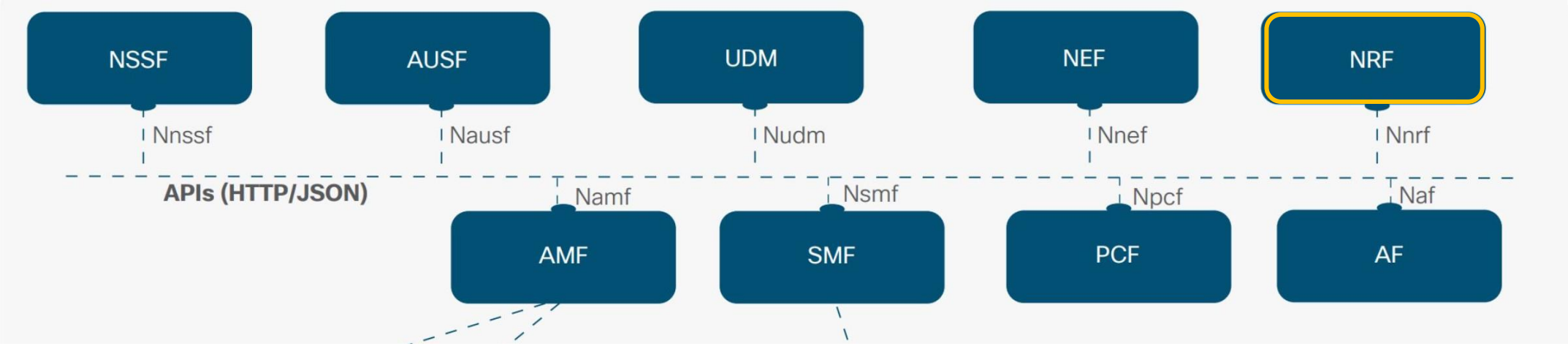
- Centralizes the management of subscriber information and profiles.
- Works closely with the Authentication Server Function (AUSF) and Access and Mobility Management Function (AMF).
- Stores user subscription data, including service plans and QoS parameters.
- Provides authentication data to the AUSF for secure access.
- Supports the Policy Control Function (PCF) by supplying necessary data for policy enforcement.
- Allows for real-time updates to subscriber information and service configurations.



5G system Service Based Architecture (SBA)

NRF: Network Repository Function

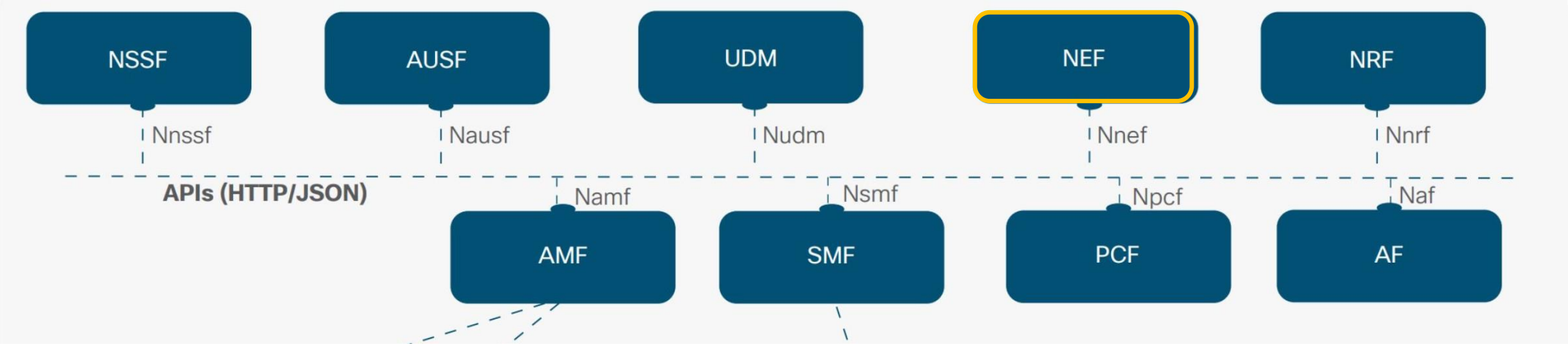
- Facilitates the discovery of network functions and services within the 5G core.
- Maintains a repository of available network functions and their statuses.
- Allows network functions to register and update their availability and capabilities.
- Provides information about the availability of network functions to other components, enabling efficient service routing.
- Assists in distributing requests among multiple instances of the same network function



5G system Service Based Architecture (SBA)

NEF: Network Exposure Function

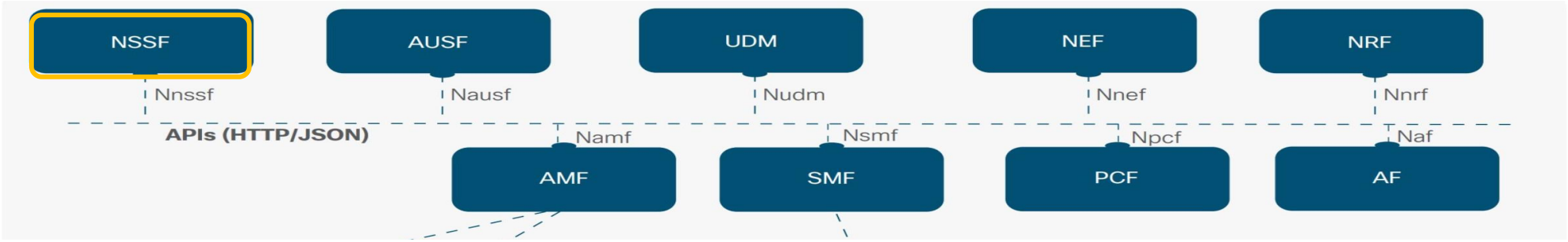
• Provides a standardized interface (API) for third-party applications to access network capabilities.
• Facilitates the integration of external services and applications with the 5G network.
•Works with the Policy Control Function (PCF) to enforce policies for external applications accessing network resources.
•Ensures secure access to network services by managing authentication and authorization for external entities.



5G system Service Based Architecture (SBA)

NSSF: Network Slicing Selection Function

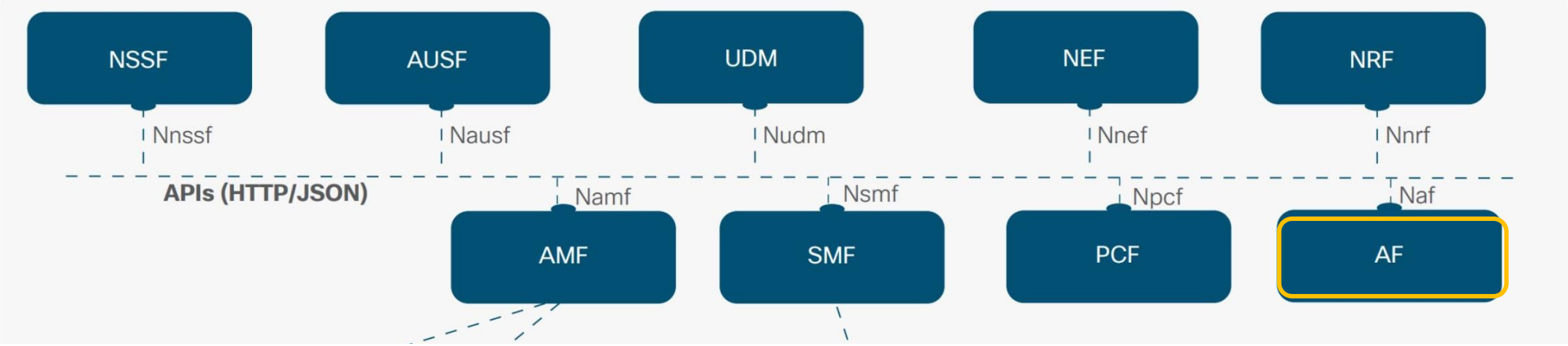
- Facilitates the selection and management of network slices based on user requirements and service needs.
- Works closely with the Policy Control Function (PCF) and the Session Management Function (SMF).
- Determines the appropriate network slice for a given user or service request based on predefined criteria.
- Assists in allocating resources to the selected network slice to ensure optimal performance.
- Supports dynamic adjustments to slice allocation based on changing network conditions and user demands.



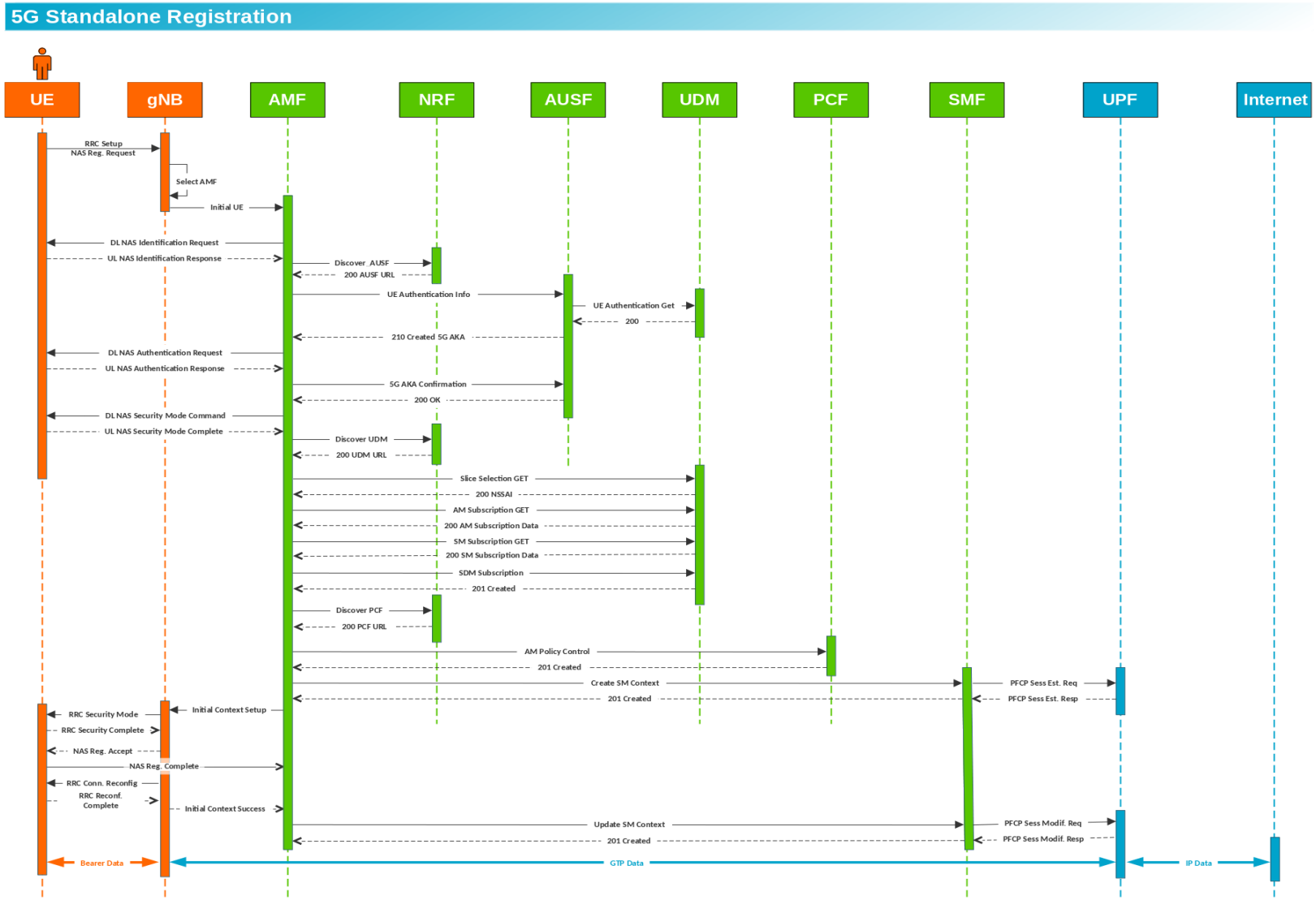
5G system Service Based Architecture (SBA)

AF: Application Function

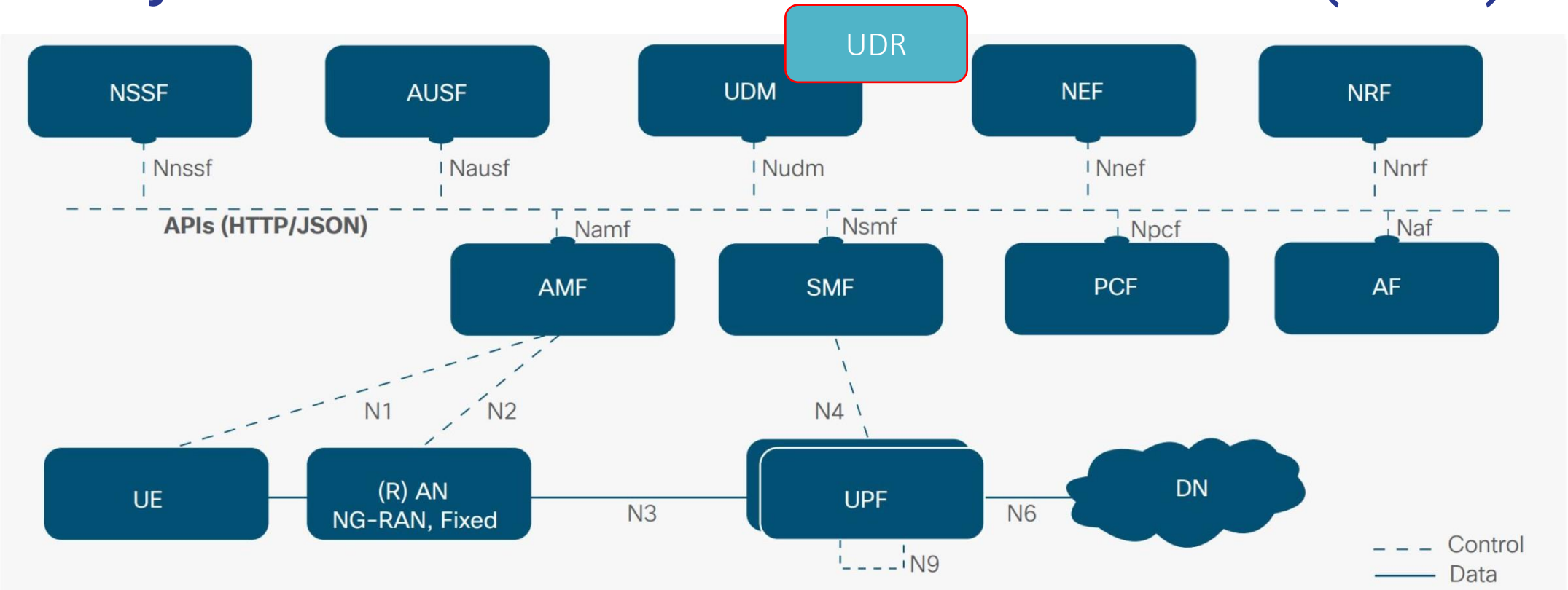
- Provides application-level services and capabilities to enhance user experiences.
- Works closely with other network functions like the Policy Control Function (PCF) and Network Exposure Function (NEF).
- Interacts with the PCF to enforce policies related to application usage and resource allocation.
- Requests QoS parameters for specific applications to ensure optimal performance.
- Tailors network resources based on application requirements and user behavior.



5G UE Registration



5G system Service Based Architecture (SBA)

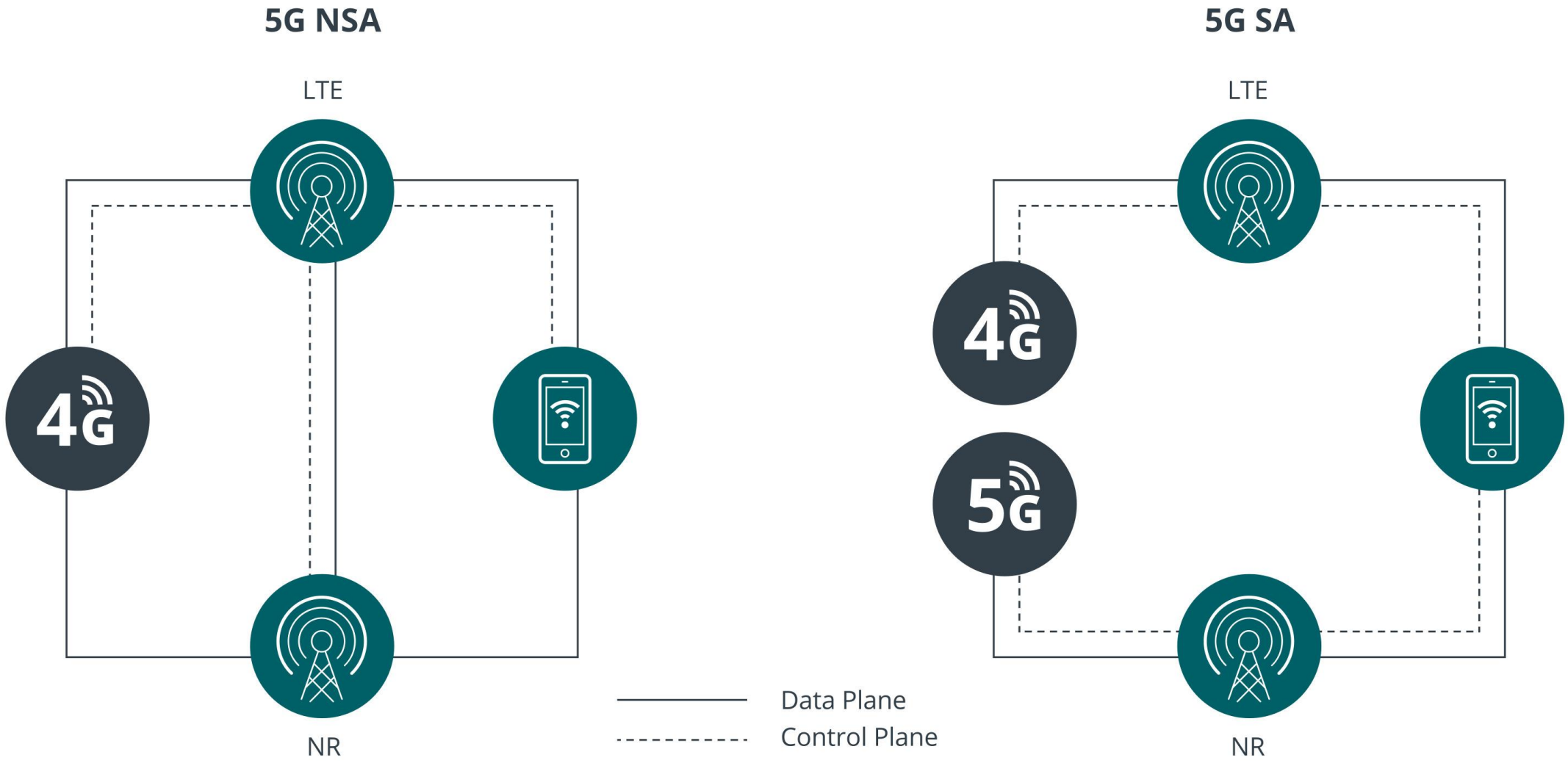


NSSF	Network Slice Selection Function
AUSF	Authentication Server Function
UDM	Unified Data Management Function
NEF	Network Exposure Function
NRF	Network Repository Function

AMF	Access and Mobility Management Function
SMF	Session Management Function
PCF	Policy Control Function
AF	Application Function

UE	User Equipment
RAN	Radio Access Network
UPF	User Plane Function
DN	Data Network

5G NSA (Non-Stand-Alone) and 5G SA (Stand-Alone) Mode



5G NSA (Non-Stand-Alone)

Relies on existing 4G LTE infrastructure for control functions while adding 5G radio access.

Features:

- **Peak Download Speeds**: 2-3 Gbps
- **Latency:** 10-20ms
- Provides enhanced data rates and capacity using 5G radio but still depends on 4G for core network functions.
- Easier and quicker to deploy as it leverages existing 4G networks.

5G SA (Stand-Alone)

Only 5G core network (5GC) and does not rely on existing 4G infrastructure.

Features:

- **Peak Download Speeds**: Can reach up to **10 Gbps** or more
- Extremely low latency, often around **1 ms**
- Full 5G capabilities, including ultra-low latency and high reliability.
- Supports advanced features like network slicing and edge computing.
- Allows for independent operation of 5G services.
- Energy efficient

5G system Service Based Architecture (SBA)

Service Based Architecture (SBA) a.k.a. Service Oriented Architecture (SOA)

- **Standardized:** Services within the same inventory (e.g. 5GC) are in compliance with the same contract design standards and have a standard communication agreement
- **Loosely coupled:** Inter-service contracts (e.g. NFs) dependency is minimized to the level that they are only aware of their existence. Interoperability between them is guaranteed
- **Scalability:** Network functions are broken down into independent services, allowing for better scalability
- **Reusable:** Resources, logic and functionalities are decomposed into multiple services to maximise code reusability
- **Composable:** Services can be composed to create new services (e.g. UPF chaining)
- **Autonomic:** Services have the control over their resources and functionalities. Minimal (or zero) external dependencies
- **Stateless:** Service do not store state for too long (or at all) of a transaction. Requests are treated independently
- **Abstract:** Inner logic is completely transparent to the consumer.
- **Discoverable:** Services can be found and identified

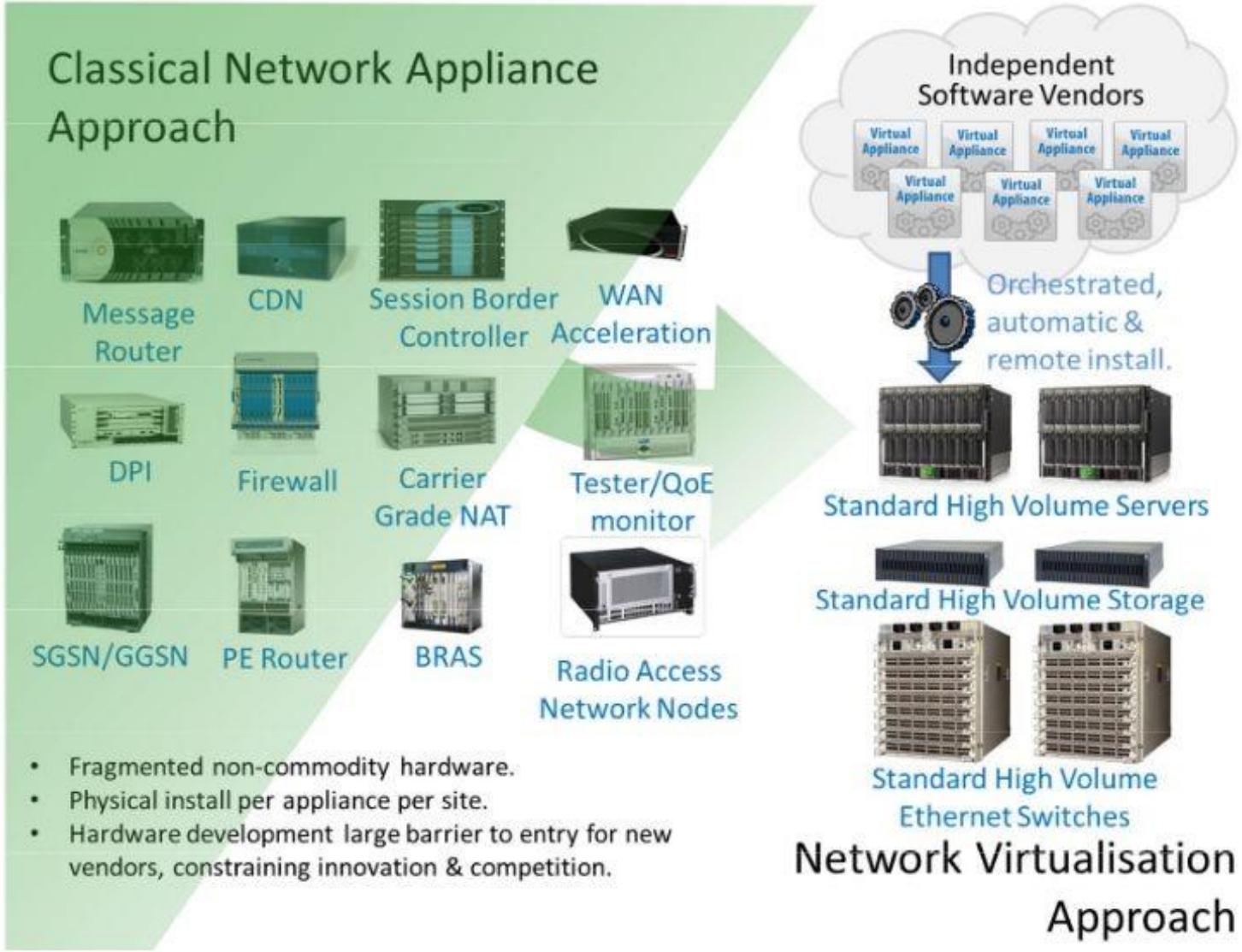
Telcos before Softwarization

- Large and increasing variety of **proprietary hardware appliances**
- One device, one big function on custom hardware
- Finding the **space and power** to accommodate these boxes is becoming increasingly difficult
- Hardware-based appliances **rapidly reach end of life**
- Hardware life-cycles are becoming shorter as technology and services innovation accelerates
- Less flexibility
- **Few places for automation**

Telcos softwarization goal

- Reduce equipment costs and power consumption through **sharing** equipment and exploiting the economies of scale of the IT industry
- Increase speed of Time to Market by minimising the typical network operator cycle of innovation
- Make network appliances **multi-version** and **multi-tenant** allowing use of a single platform for different applications, users and tenants
- Allow network operators to share resources across services and across different customer bases
- Allow fine grained **service placement to optimize cost/quality** and enable rapid **scale** up/down
- **Generalize automation** from OSS/BSS to deepest network components
- Enable a wide variety of ecosystems and encourages **openness**

Technical Enablers of 5G: **NFV**



Softwarized network appliances

+

Deployment to IT Datacenters-like infrastructure

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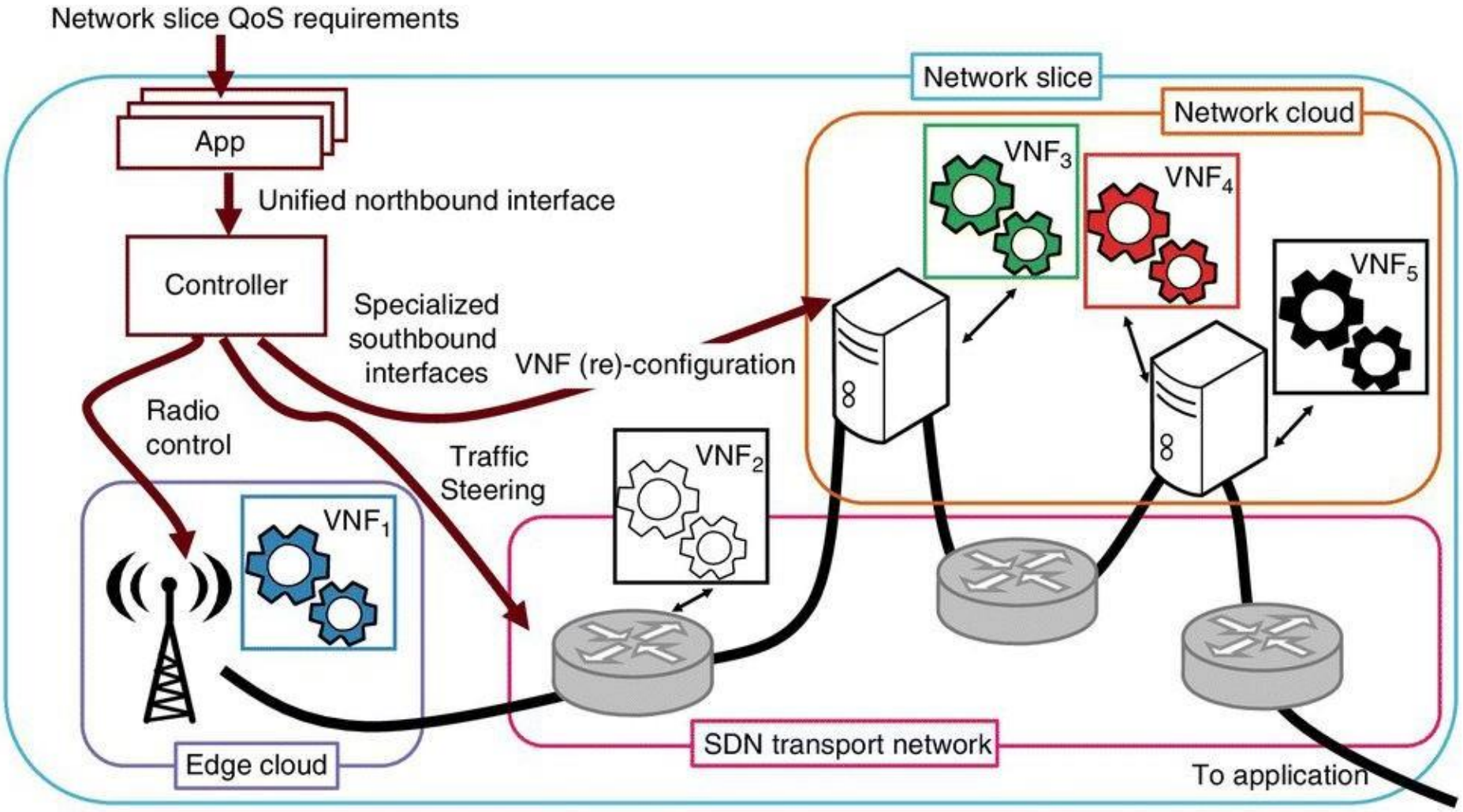
Cloudification of network appliances

Technical Enablers of 5G: **SDN**



5GC Open Source projects

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