



SVEUČILIŠTE U ZAGREBU



Fakultet
elektrotehnike i
računarstva

Master Programme

Computing

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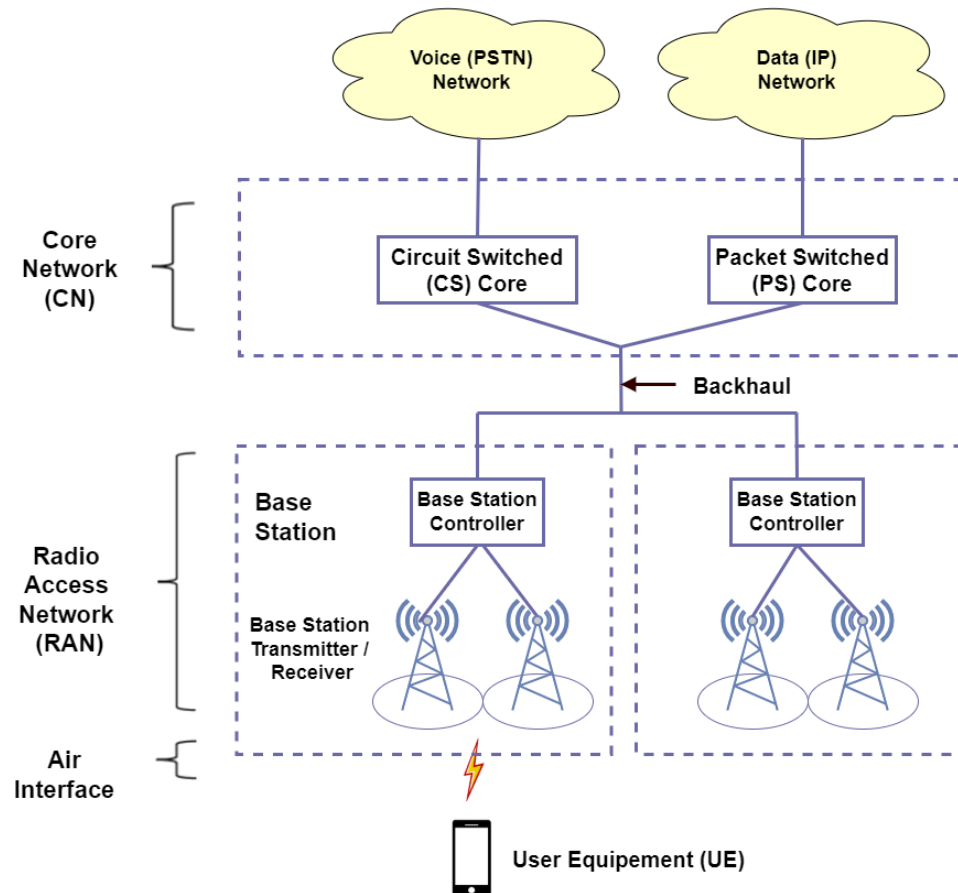


Advanced Architectures of Telecommunication Networks



Basic 5G network architecture: key
network components and interfaces

2G / 3G mobile network architecture



- **Core Network:**

- Connects to voice and data networks
- Provides Security and Authentication
- Billing / Charging
- Roaming

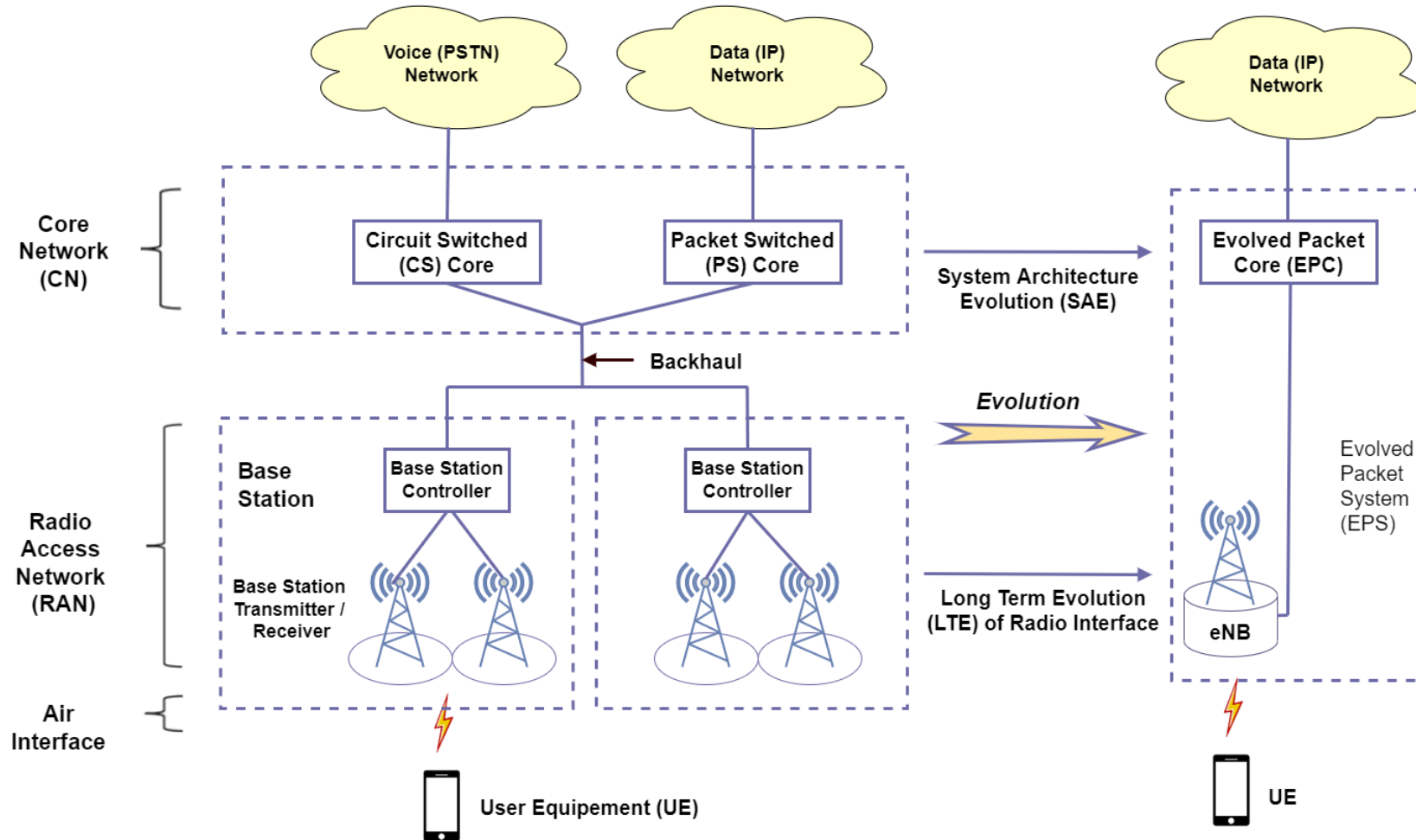
- **Backhaul:**

- Connects access network with core network
- Example: fiber, microwave, satellite, etc.

- **Access Network:**

- Connects devices over the air
- Allows mobility and handovers

4G mobile network architecture

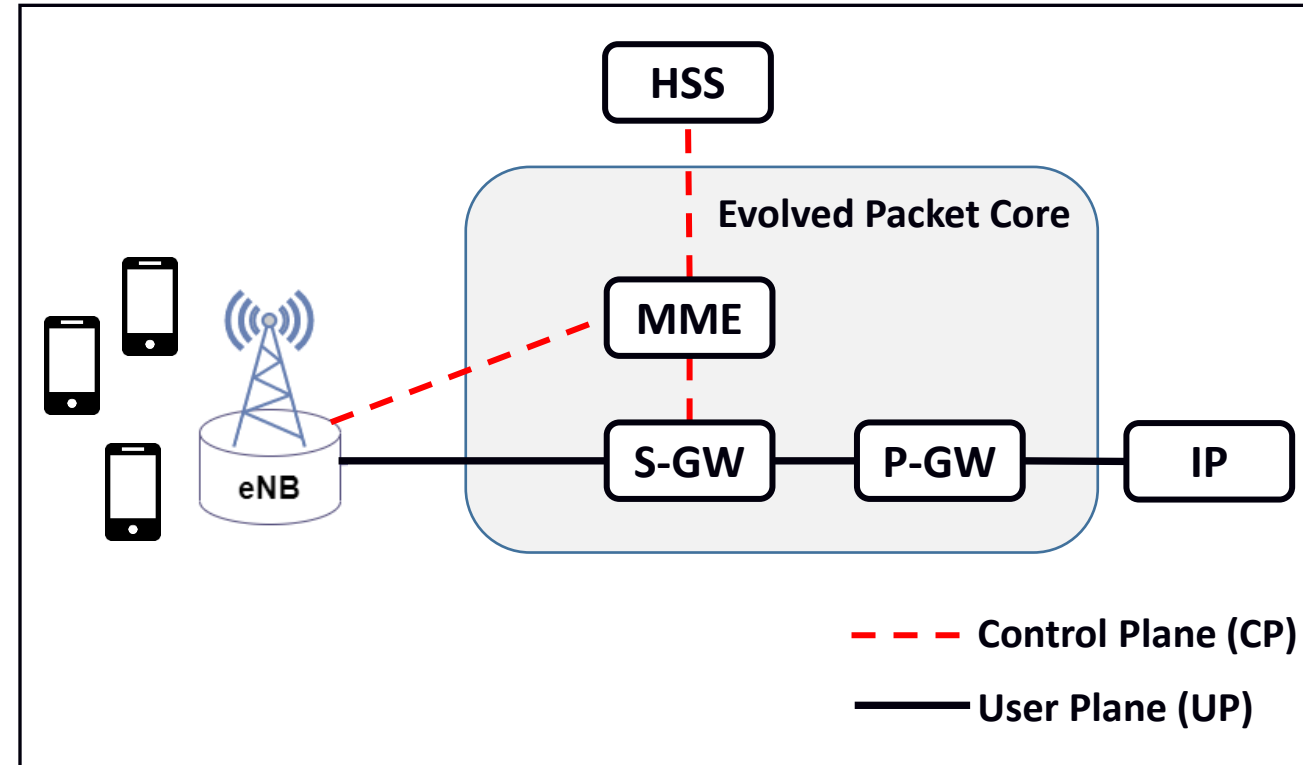


4G LTE Evolved Packet Core (EPC)

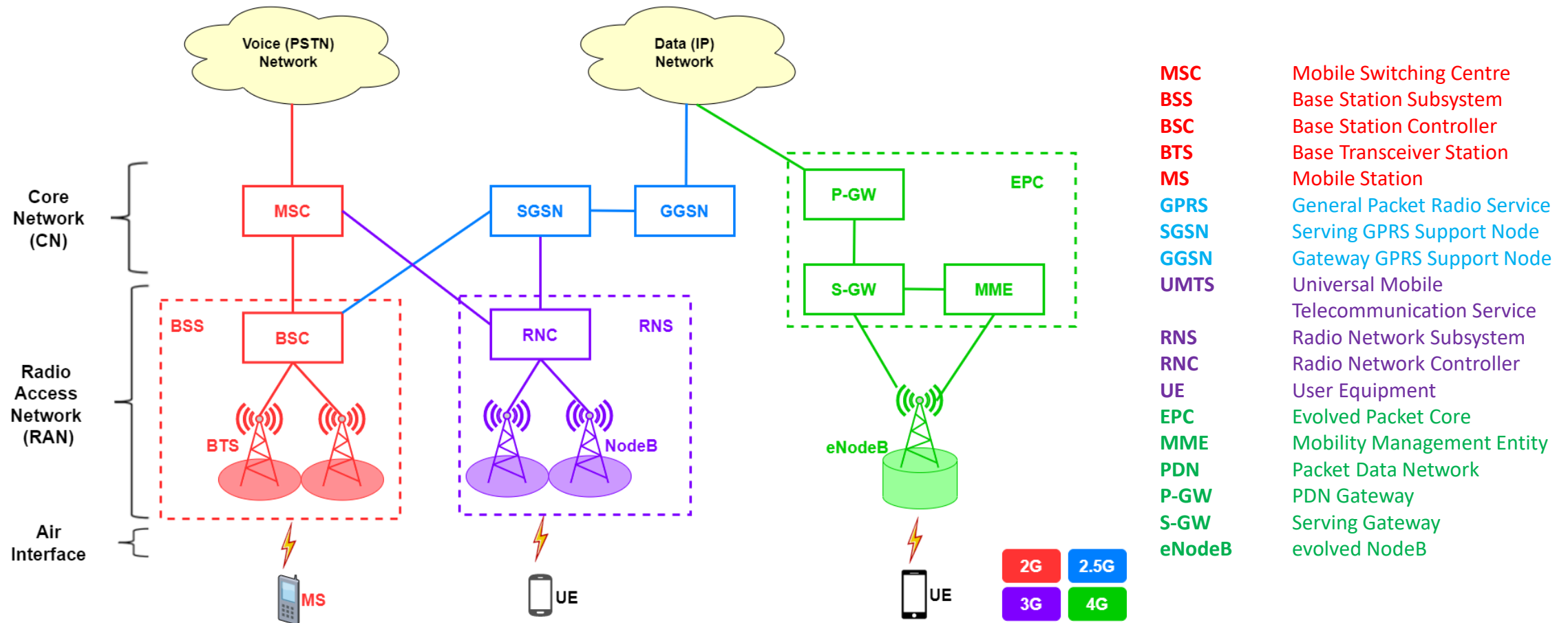
User equipment (UE) connects to the EPC through eNodeB (eNB) base stations.

Four core elements:

- **Serving Gateway (S-GW):** manages User Plane (UP) data
- **Mobility Management Entity (MME):** handles Control Plane (CP) functions
- **PDN Gateway (P-GW):** connects the EPC to external IP networks
- **Home Subscriber Server (HSS):** manages UE authentication



2G - 4G reference point network architecture



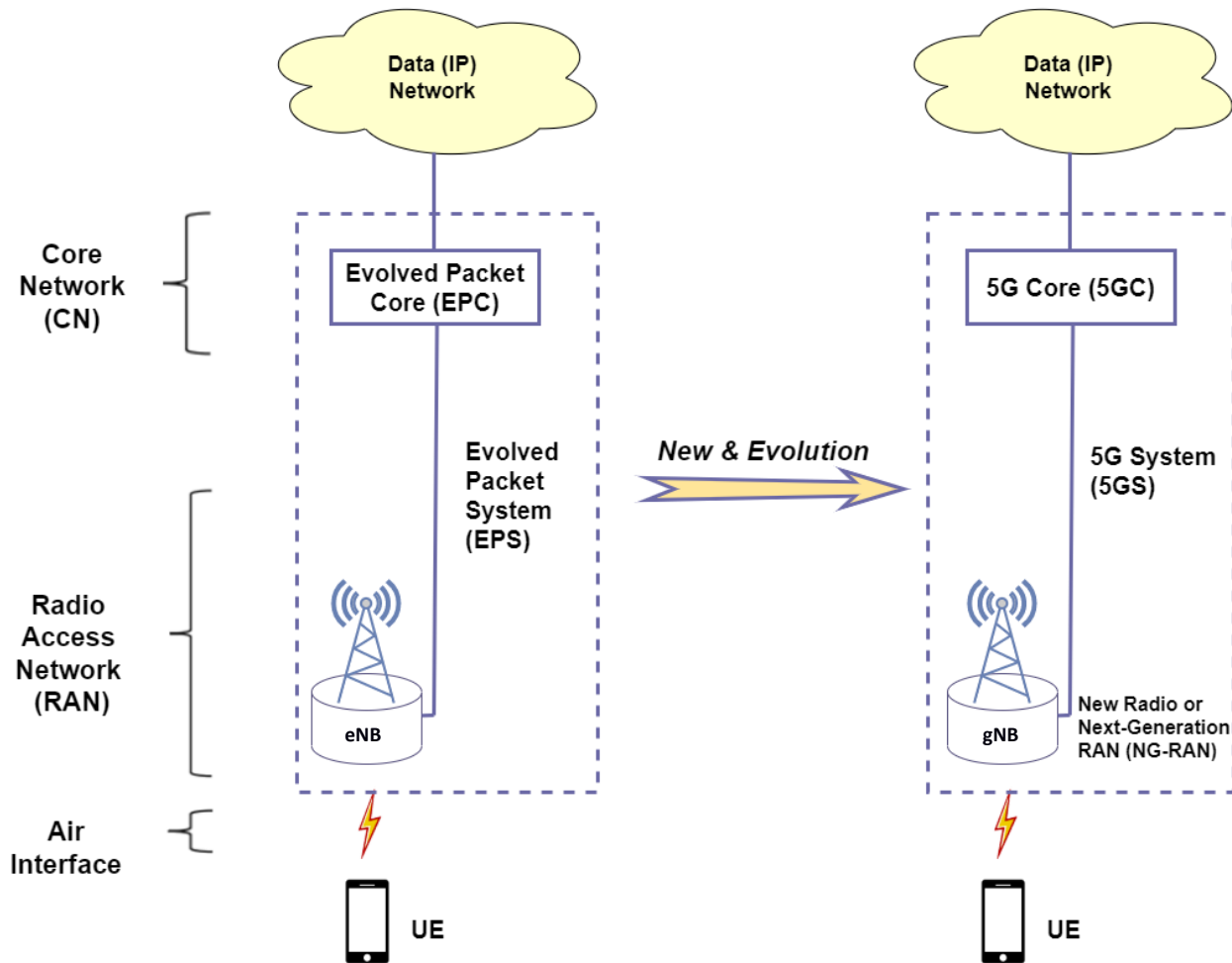
Control and User Plane Separation (CUPS)

- Provides the architecture enhancements for the separation of functionality in the S-GW (Serving Gateway) and P-GW (Packet Data Network Gateway)
- Enables flexible network deployment and operation, by distributed or centralized deployment and the independent scaling between control plane and user plane functions

Advantages of CUPS Architecture

- Reducing **Latency** on application service, e.g. by selecting User plane nodes which are closer to the RAN or more appropriate for the intended UE usage type without increasing the number of control plane nodes
- Supporting **Increase of Data Traffic**, by enabling to add user plane nodes without changing the number of S-GW and P-GW in the network
- **Locating and Scaling** the CP and UP resources of the EPC nodes independently
- **Independent evolution** of the CP and UP functions
- Enabling **Software Defined Networking** to deliver user plane data more efficiently

5G mobile network architecture



- 5G System is defined as 3GPP system consisting of:
 - **5G Access Network (AN),**
 - **5G Core Network (5GC),** and
 - **User Equipment (UE)**
- The 5G System provides data connectivity and services
- An NG-RAN node is either:
 - a **gNB**, for New Radio (NR) access, or
 - an **ng-eNB**, for LTE radio access

eNB, ng-eNB, gNB

- **eNodeB (eNB):** LTE access network from 3GPP Rel-8 up to 3GPP Rel-14
- **Next generation eNodeB (ng-eNB):** LTE access network from 3GPP Rel15 onwards
 - node providing RAN user plane and control plane protocol terminations towards the UE, and connected via the NG interface to the 5GC
- **Next generation NodeB (gNB):** 5G access network from 3GPP Rel-15 onwards
 - node providing NR user plane and control plane protocol terminations towards the UE, and connected via the NG interface to the 5GC

gNB

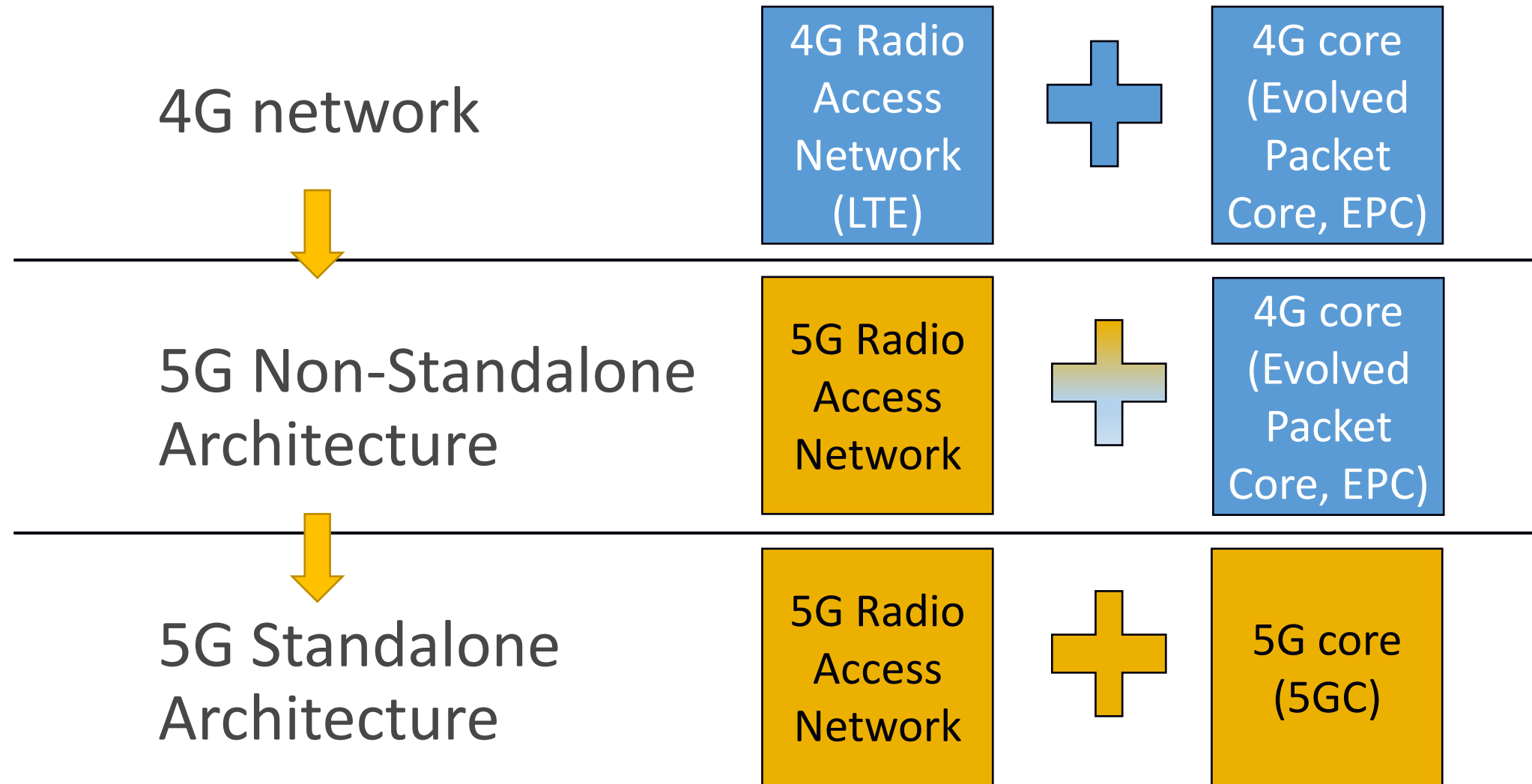
- The gNB (or ng-eNB) is responsible for all radio-related functions in one or several cells:
 - radio resource management,
 - admission control,
 - connection establishment,
 - routing of user-plane data,
 - routing of control-plane information, and
 - quality-of-service (QoS) flow management
- A gNB is a *logical* node and not a physical implementation

5G spectrum and frequencies

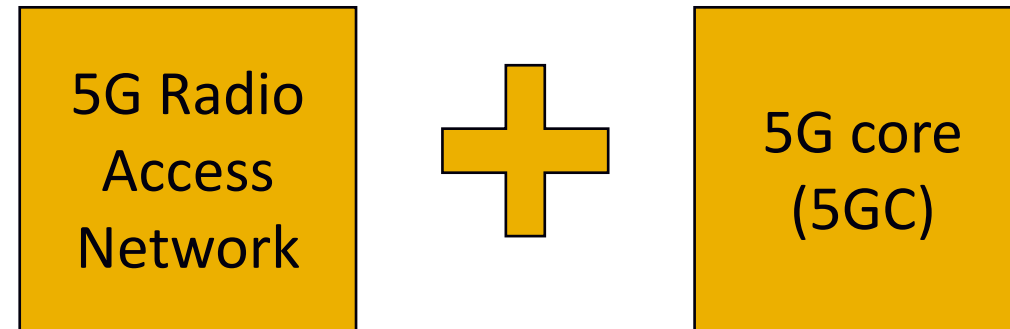


Qualcomm Technologies, Making 5G NR a reality, December 2016

Migration from 4G to 5G



5G Standalone Architecture



- 5G Core → implies a **technology shift** with:
 - adoption of the new 3GPP defined **service-based architecture**
 - network functions built on **cloud native technology**

5G Core (5GC) network

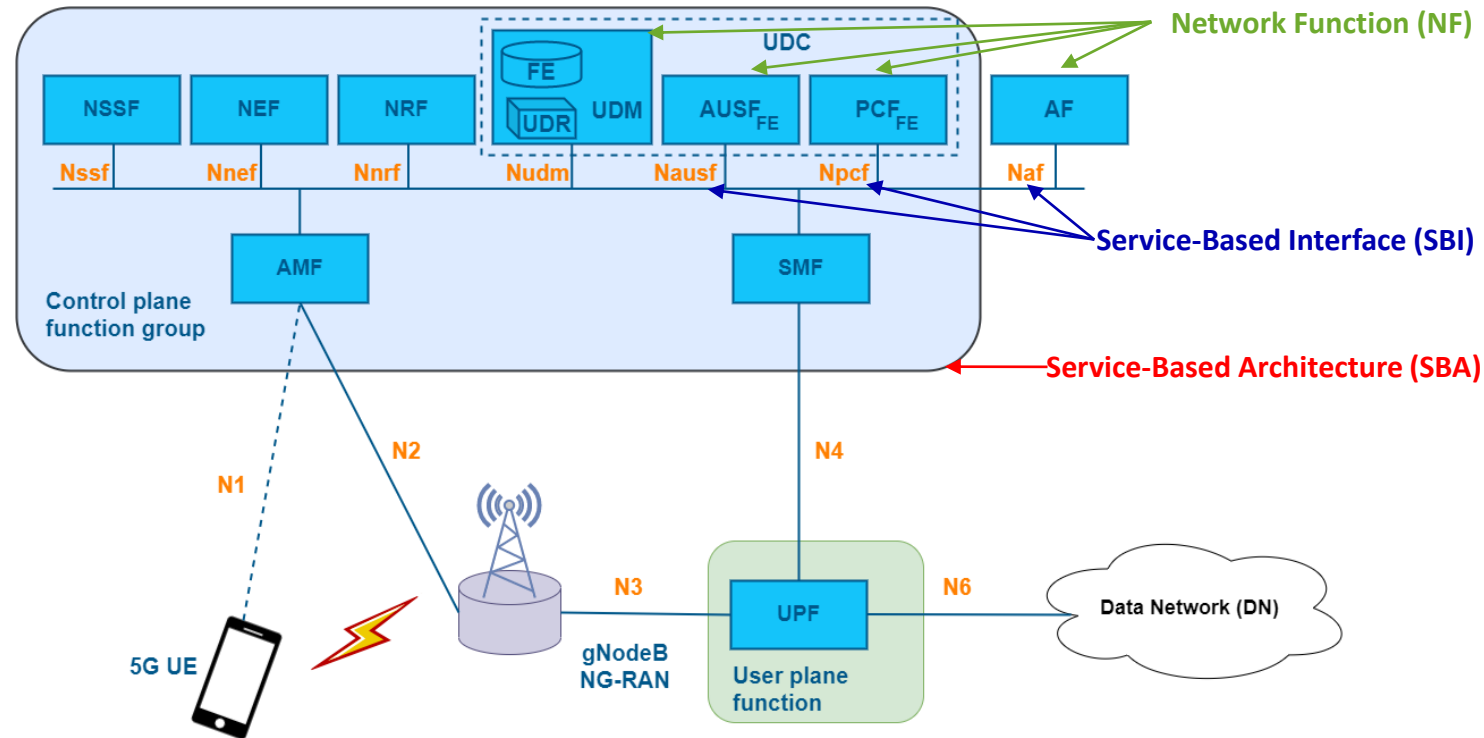
- Leverages service-based interactions and separates the User Plane (UP) functions from the Control Plane (CP) functions
- Allows independent scalability, evolution and flexible deployments
- Defined with a converged core network with a common interface between Access Network (AN) and the Core Network (CN)
 - minimizes the dependencies between the AN and the CN

5GC: IT network principles + cloud-native design approach

- Based on a **Service-Based Architecture (SBA)**
- A network function (NF) is formed by a combination of small pieces of software code called **microservices**
 - some microservices can be re-used for different NFs, making implementation more effective and facilitating independent life-cycle management
 - allows upgrades and new functionalities to be deployed with zero impact on running services

Each Network Function (NF) offers one or more services to other NFs via Application Programming Interfaces (APIs)

5G Service-Based Architecture (SBA)



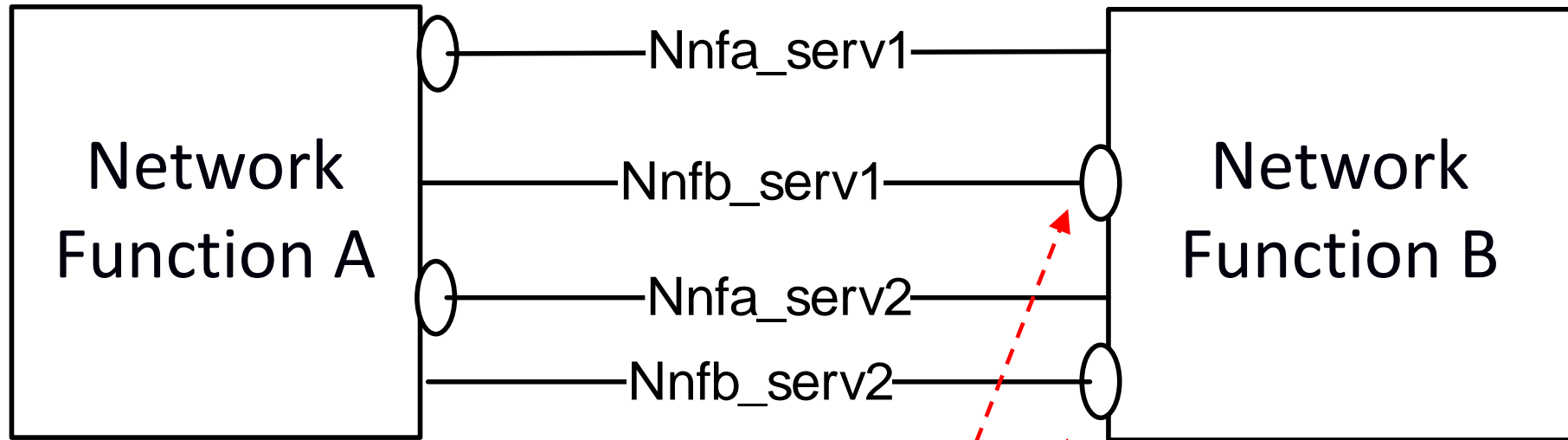
AF	Application Function
AMF	Access and Mobility management Function
AUSF	Authentication Server Function
DN	Data Network
FE	Front End
NEF	Network Exposure Function
NRF	NF Repository Function
NSSF	Network Slice Selection Function
PCF	Policy Control Function
(R)AN	(Radio) Access Network
SMF	Session Management Function
UDM	Unified Data Management
UDR	Unified Data Repository
UE	User Equipment
UPF	User Plane Function

- All interactions are abstracted as: Request-Response, Subscription-Notify
- System procedures are described as a sequence of NF service invocations

Note: the **Service-based architecture** applies to **signaling functionality** only, NOT to the transfer of user data!

Network functions

- Each entity in the architecture = **Network Function (NF)**
- Entities of the SBA:
 - each of the interfaces to the NFs is a **Service-Based Interface (SBI)**, e.g. Nsmf
 - each NF supports one or more Network Function Services exposed via its SBI
 - each Network Function Service supports one or more Operations
- Operations can be invoked by other entities (Consumers)
- SBI and Reference Points (RPs) are two different ways to model interactions between architectural entities
 - RP is a conceptual point at the conjunction of two non-overlapping functional groups
 - RP can be replaced by one or more SBI which provide equivalent functionality



A NF may expose one or more services through
Service based interfaces
(SBIs)

Relationship between Service-Based Interfaces and Reference Points

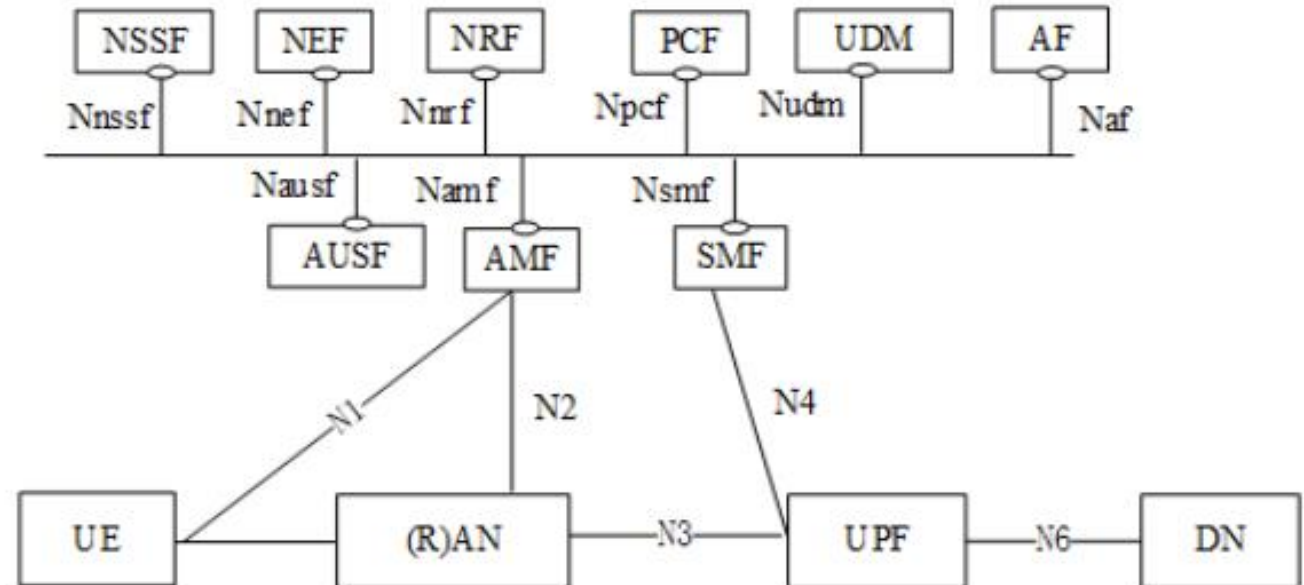
- Service-Based Interfaces and Reference Points are two different ways to model interactions between architectural entities
 - **Reference Point**: a conceptual point at the conjunction of two non-overlapping functional groups
 - **Service-based Interface (SBI)**: represents how a set of services is provided/exposed by a given NF
 - a reference point can be replaced by one or more **SBIs** which provide equivalent functionality

5G architecture

- The 5G architecture is defined as service-based and the interaction between network functions is represented in two ways:
 - **a service-based representation**, where network functions within the Control Plane enables other authorized network functions to access their services; this representation also includes point-to-point reference points where necessary
 - **a reference point representation**, shows the interaction exist between the NF services in the network functions described by point-to-point reference point between any two network functions

Service-based representation

AF	Application Function
AMF	Access and Mobility management Function
AUSF	Authentication Server Function
DN	Data Network
NEF	Network Exposure Function
NRF	NF Repository Function
NSSF	Network Slice Selection Function
PCF	Policy Control Function
(R)AN	(Radio) Access Network
SMF	Session Management Function
UDM	Unified Data Management
UE	User Equipment
UPF	User Plane Function



Reference point representation

NG1: Reference point between the UE and the AMF

NG2: Reference point between the gNB and the AMF

NG3: Reference point between the gNB and the UPF

NG4: Reference point between the SMF and the UPF

NG5: Reference point between the PCF and an AF

NG6: Reference point between the UPF and a DN

NG7: Reference point between the SMF and the PCF

NG8: Reference point between UDM and AMF

NG9: Reference point between two Core UPFs

NG10: Reference point between UDM and SMF

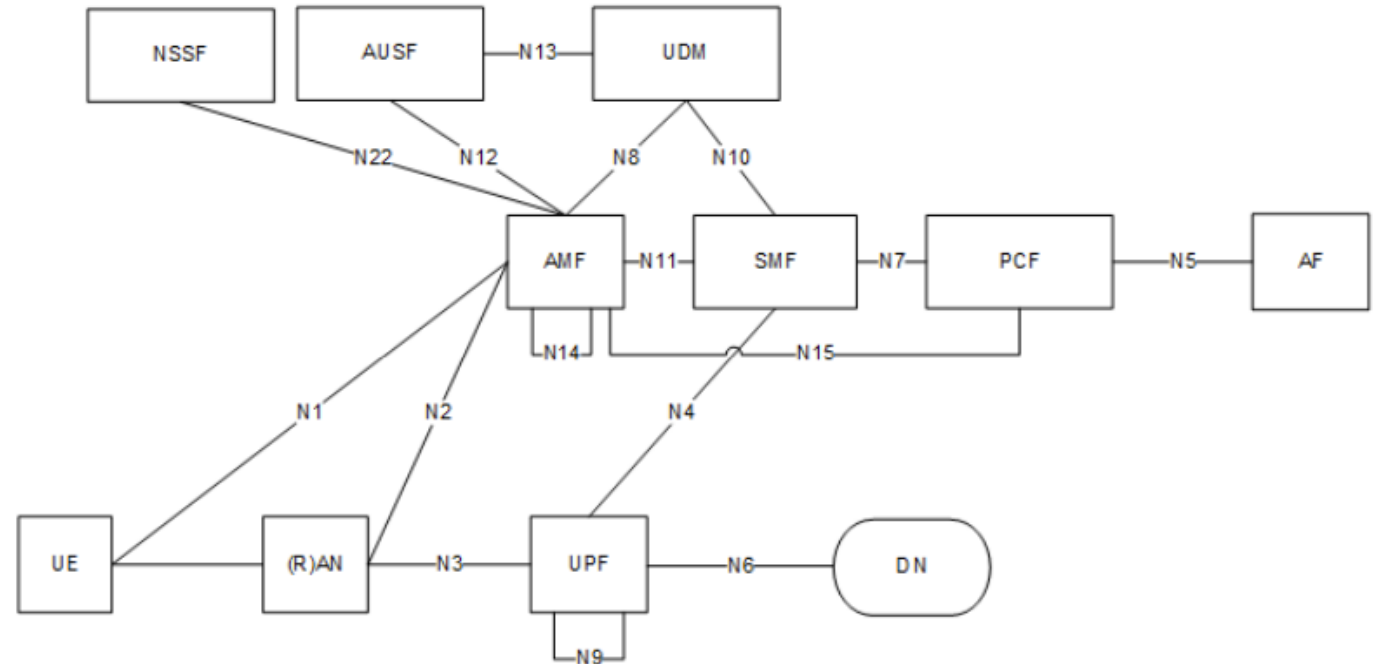
NG11: Reference point between AMF and SMF

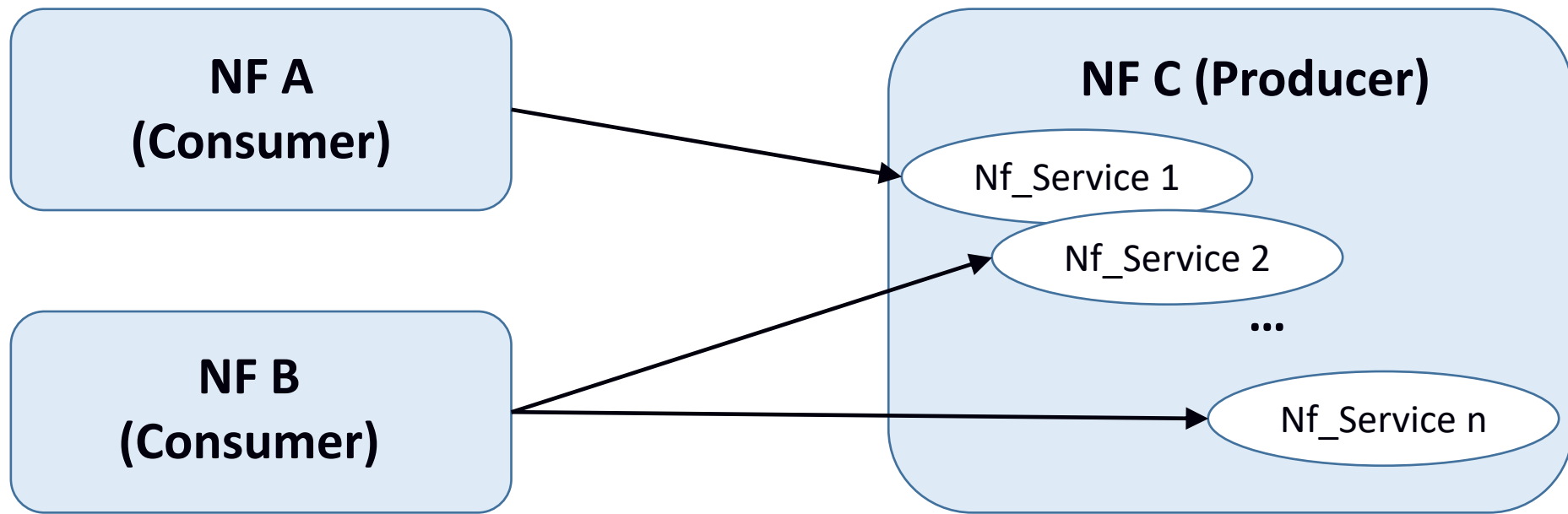
NG12: Reference point between AMF and AUSF

NG13: Reference point between UDM and AUSF

NG14: Reference point between 2 AMF

NG15: Reference point between the PCF and the AMF in case of non-roaming scenario, V-PCF and AMF in case of roaming scenario, etc.





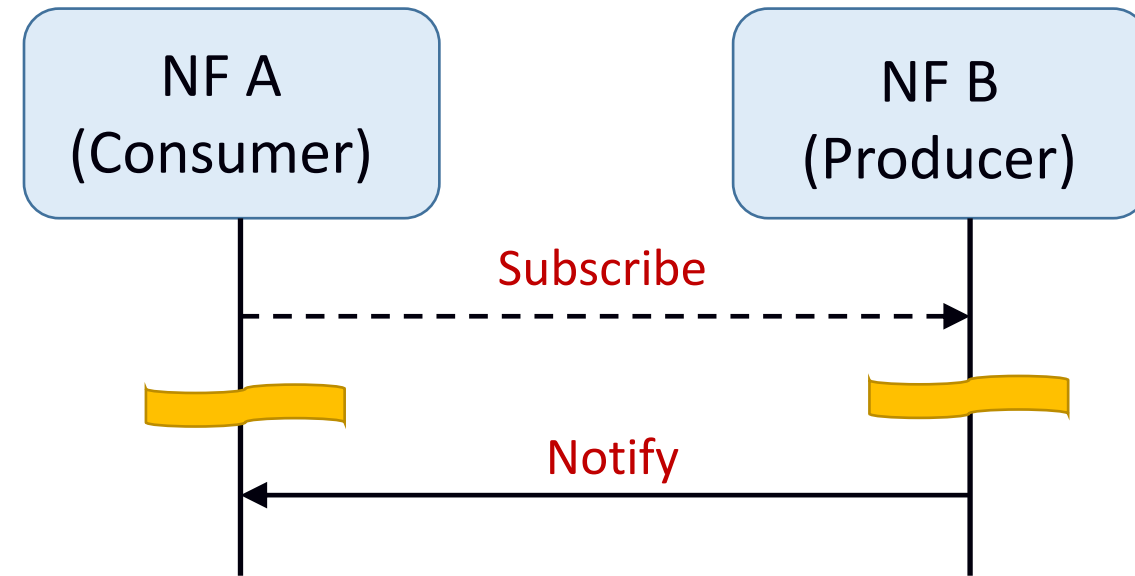
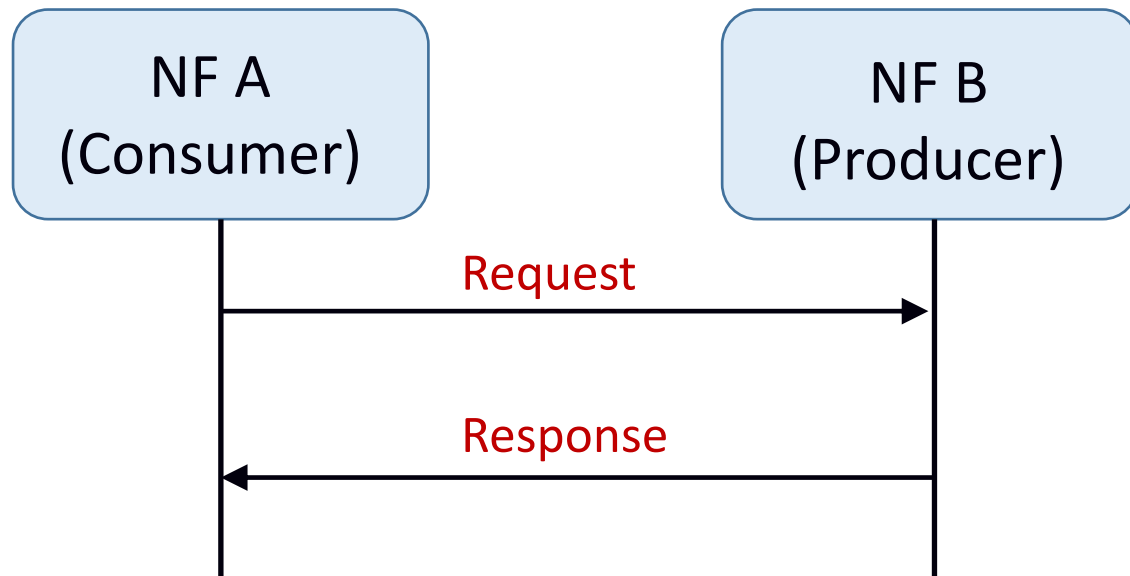
When two NFs communicate they take on two distinct roles:

- **Service Consumer** – sends a request
- **Service Producer** – offers a service and triggers some action based on the request; after completed action, responds back to the Service Consumer

An **NF Service** is one type of capability exposed by an NF (NF Service Producer) to other NFs (NF Service Consumers). The service is:

- self-contained
- reusable
- managed independently of other NF services offered by the same NF

Two types of primitive operations:



HTTP REST Interfaces

- The communication method defined for 5G Core relies on the widely used **HTTP REST** (*Representational State Transfer*) paradigm →
 - a set of rules or guidelines that define how web communication technologies access services from distributed applications using APIs
 - specifies how to implement the communication between different software modules in a networked architecture
- This is the standard way of designing IT networking applications today, and has been selected by 3GPP as a means of allowing for tighter integration between mobile networks and surrounding IT systems

HTTP REST Interfaces (cont'd)

- Uses message syntax from the widely used HTTP protocol
- Relies on the concept of Resource Modeling → a distributed software application can be addressed through Uniform Resource Identifiers (URIs)
- Important aspect: all communication must include the full set of information needed for a specific processing action. Does not rely on previous messages → **stateless!**

Main HTTP methods used:

- **GET**—used to fetch data from a server; does not change any data.
- **POST**—used to send data to a server
- **PUT**— also used to send data to a server, but it replaces existing data
- **DELETE**—used to remove data from a server

Mandatory components of a 5G architecture

- **AMF (Access and Mobility Management Function):**
 - manages all UE related functions
 - establishes a signaling connection towards the UE
- **SMF (Session Management Function):**
 - sets up connectivity for the UE towards data networks
 - manages the User Plane for the connectivity
 - establishes, modifies, and releases sessions
- **UPF (User Plane Function)**
 - processes and forwards user data; connects to external IP networks
 - controlled by the SMF

Mandatory components of a 5G architecture (cont'd)

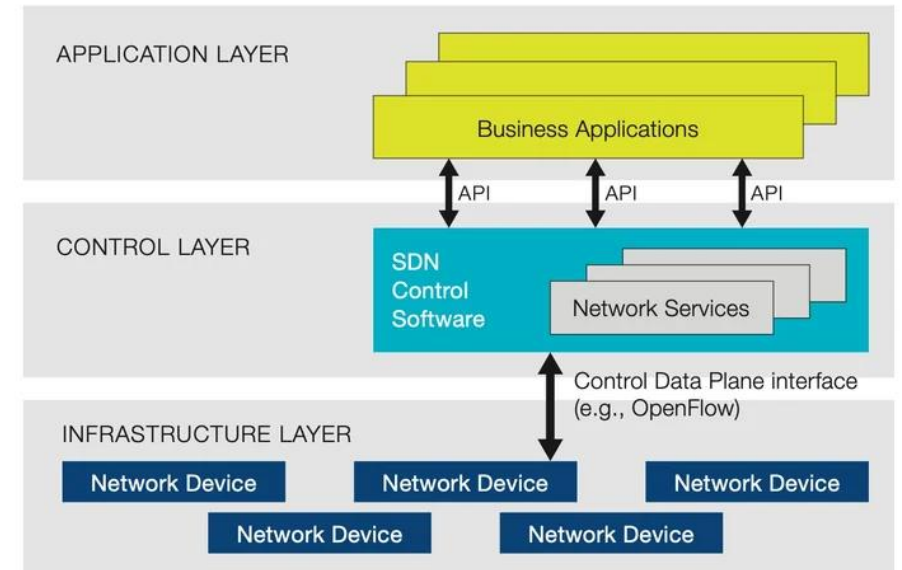
- **NRF (Network Repository Function)**
 - a repository of profiles of the NFs available in the network
- **AUSF (Authentication Server Function)**
 - handles authentication in the home network
 - provides security parameters
- **UDM (Unified Data Management)**
 - a front-end for user subscription data stored in the UDR
- **UDR (Unified Data Repository)**
 - database where various types of data is stored (e.g., subscription data, data defining various types of network or user policies)

New technologies in 5G – brief reminder

- Software-Defined Networks (SDN)
- Network Function Virtualization (NFV)
- Multi-access Edge Computing (MEC)

SDN

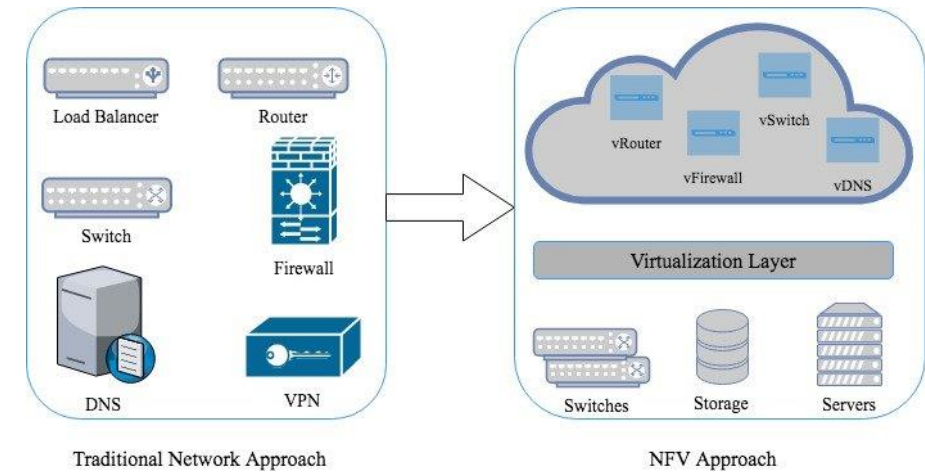
- The physical separation of the network control plane from the forwarding plane
- Enables directly programmable network control and abstraction of the underlying infrastructure from applications and network services



<https://www.sdxcentral.com/networking/sdn/definitions/what-the-definition-of-software-defined-networking-sdn/>

NFV

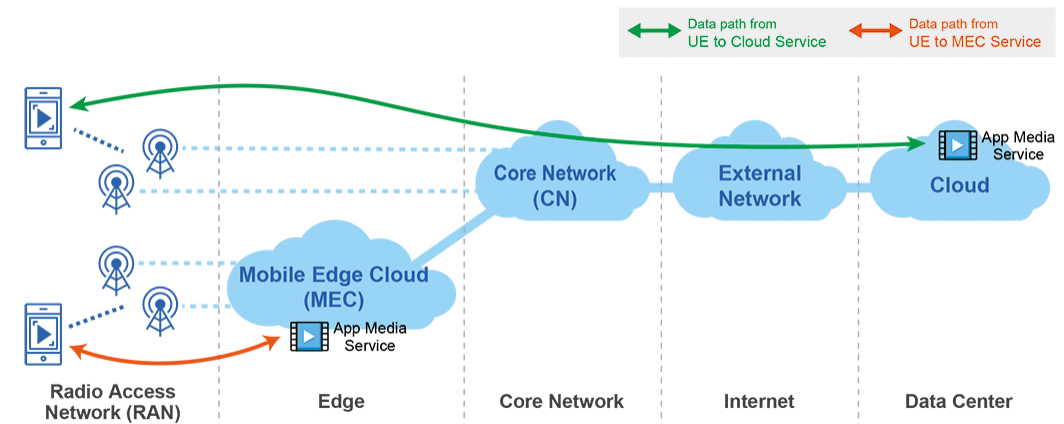
- A network architecture or concept used to virtualize entire network node functions, such as routers, firewalls, and load balancers
- Involves implementing network functions in a software that can run on a range of industry standard server hardware



Alwakeel, Ahmed & Alnaim, Abdulrahman & Fernández, Eduardo. (2019). Toward a Reference Architecture for NFV. 1-6

MEC

- Moves the computing of traffic and services from a centralized cloud to the edge of the network closer to the user
- The network edge analyzes, processes, and stores the data
- MEC reduces latency and brings real-time performance to high-bandwidth applications



<https://devopedia.org/multi-access-edge-computing>