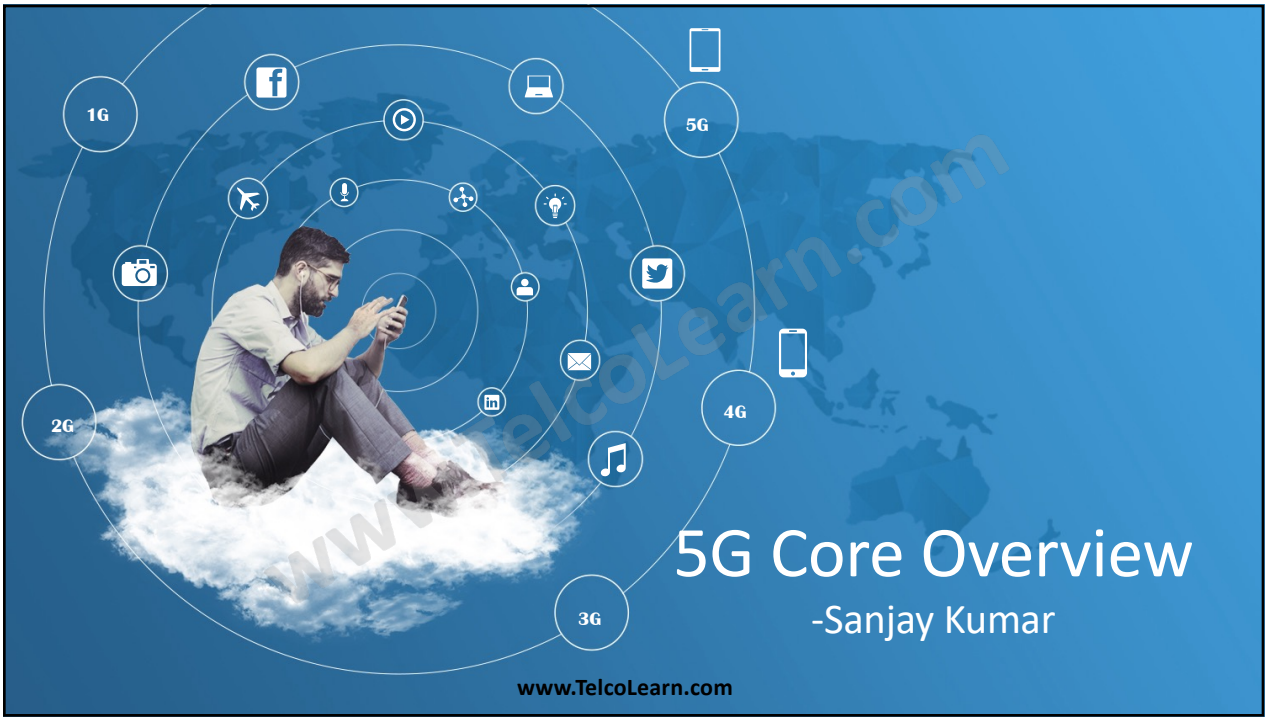

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Course Structure

1. 5G Core Overview
2. 5G Core Network Protocols
3. 5G Security and Call Flows
4. Network Slicing
5. Orchestration and MEC
6. 5G-4G Interworking, HO, VoNR, NEF

2

5G Core Overview

- Evolution of 5G
- KPI Requirements of 5G
- Introduction to 5G Networks
- EPC Limitation
- 5G Core Network Principals
- 5G Core Network Functions
- 5G Identities

3

Evolution of 5G

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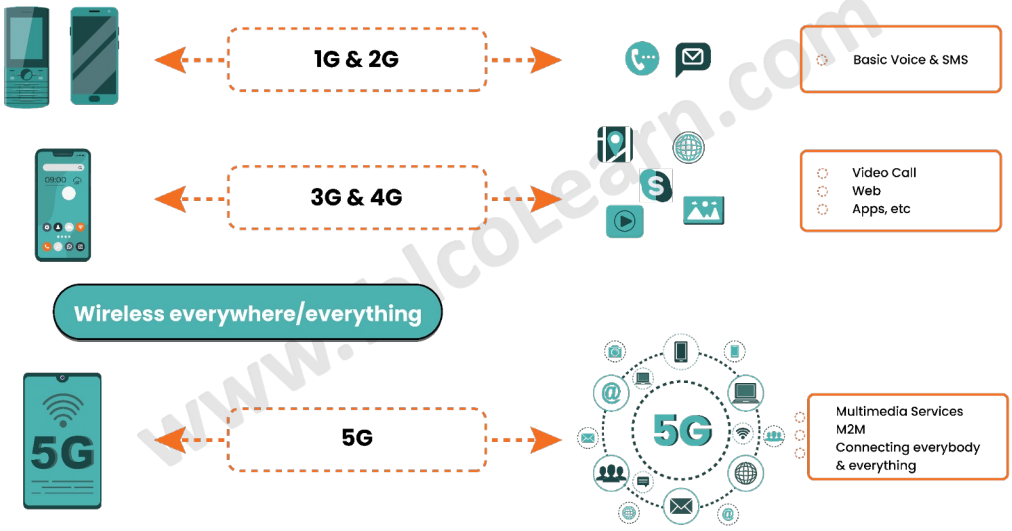
5G Objectives



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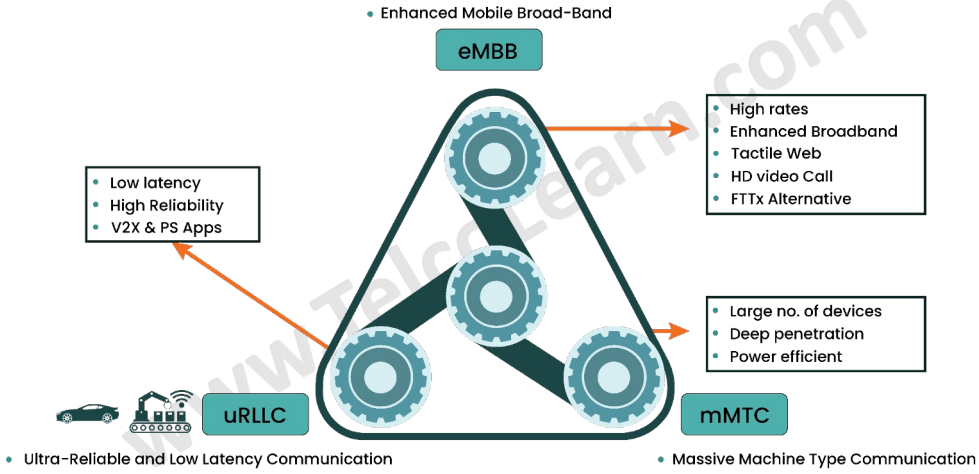
5G Service Verticals



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Understanding the KPI Requirements of 5G networks

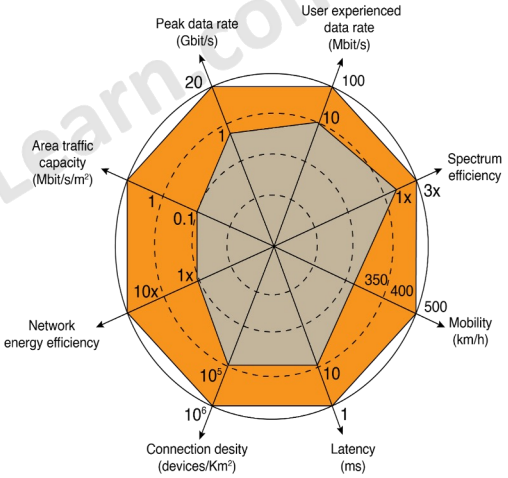
Requirements for IMT-2020 RAT

Capability	Description	5G requirement	Usage Scenario
Downlink peak data rate	Minimum maximum data rate technology must support	20 Gbit/s	eMBB
Uplink peak data rate		10 Gbit/s	eMBB
User experienced downlink data rate	Data rate in dense urban test environment 95% of time	100 Mbit/s	eMBB
User experienced uplink data rate		50 Mbit/s	eMBB
Latency	Radio network contribution to packet travel time	4 ms	eMBB
		1 ms	URLLC
Mobility	Maximum speed for handoff and QoS requirements	500 km/h	eMBB/URLLC
Connection density	Total number of devices per unit area	$10^6/km^2$	mMTC
Energy efficiency	Data sent/received per unit energy consumption (by device or network)	Equal to 4G	eMBB
Area traffic capacity	Total traffic across coverage area	10 $Mbps/m^2$	eMBB
Peak downlink spectrum efficiency	Throughput per unit wireless bandwidth and per network cell	30 bit/s/Hz	eMBB

IMT Requirements for RAT

- Peak data rate (up to 20 Gbps/device)
- User experienced data rate (100 Mbps/device)
- **Connection density** (1 million devices/km^2)
- **Energy efficiency** (1/100 Joule/bit for both air interface and network)
- **Spectrum efficiency** (3 times the bps/Hz of LTE-A)
- **Area traffic capacity** (10 Mbps/m^2)
- **Latency** (as low as 1 ms)
- **Mobility** (500 km/h and seamless transfer)

Enhancement of key capabilities from IMT-Advanced to IMT-2020



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Introduction to 5G Networks

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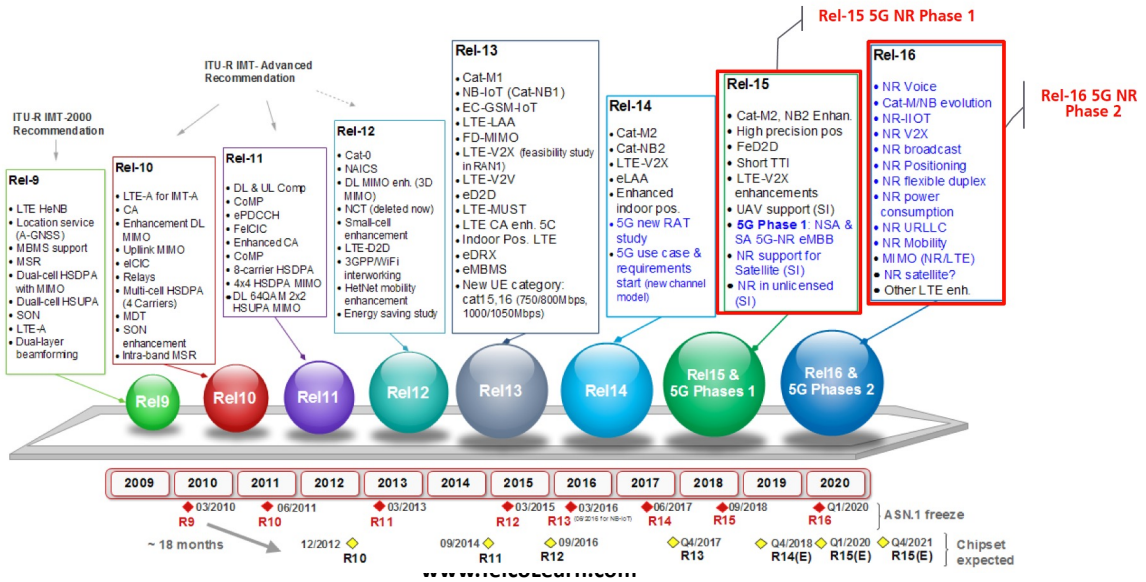
3GPP Evolutions



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3GPP Releases-5G

Version	Released	Information
Release 15	2017 Q4	First NR ("New Radio") release. Support for 5G Vehicle-to-x service, IP Multimedia Core Network Subsystem (IMS), Future Railway Mobile Communication System.
Release 16	2020 Q2	The 5G System - Phase 2: 5G enhancements, NR-based access to unlicensed spectrum (NR-U), Satellite access.
Release 17	2022 Q2	5G NR: MIMO, Spectrum Sharing enhancements, UE Power Saving and Coverage Enhancements. Enhanced support of: non-public networks, Industrial Internet of Things, edge computing in 5GC, access traffic steering, switch and splitting support, network automation for 5G, network slicing, advanced V2X service, devices having multiple USIMs, proximity-based services in 5GS,5G multicast-broadcast services, Unmanned Aerial Systems (UAS), satellite access in 5G, 5GC location services, Multimedia Priority Service.

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EPC Limitations

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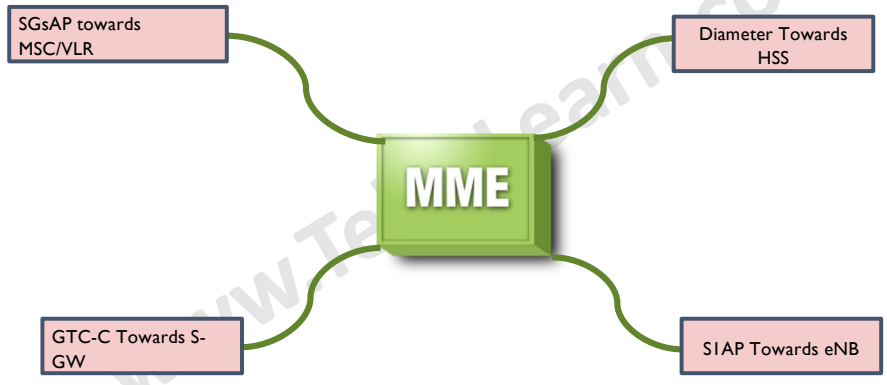
EPC Limitation 1 - To many Protocols



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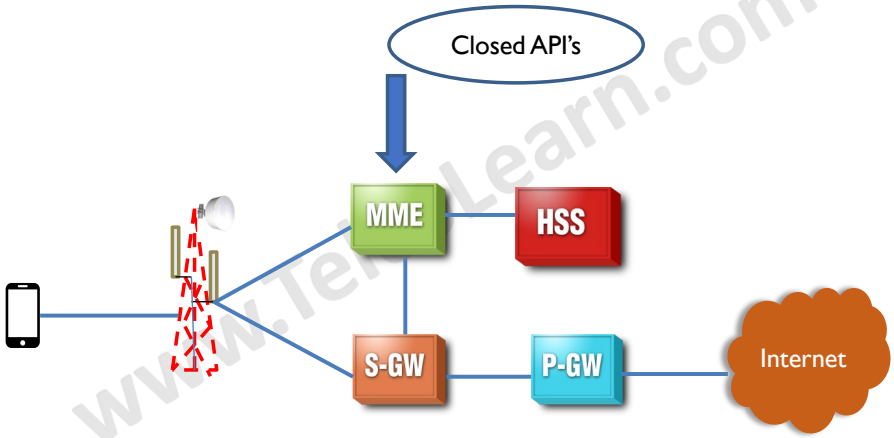
EPC Limitation 2 - Closed API's



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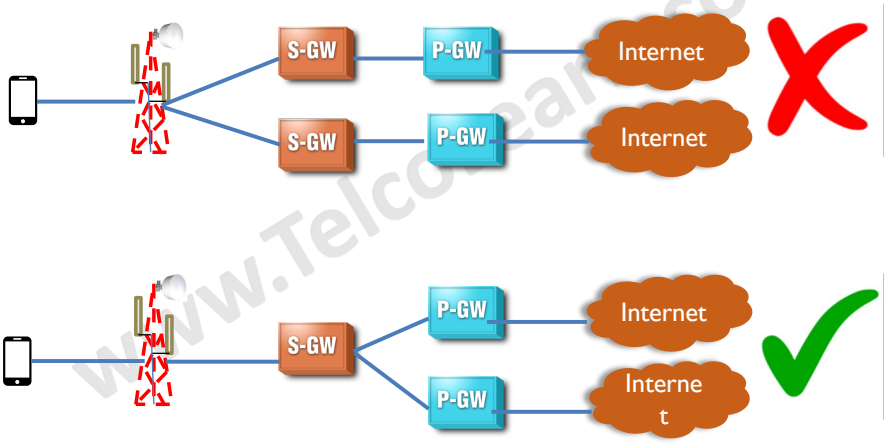
EPC Limitation 3 - Gateway Selection Inflexible



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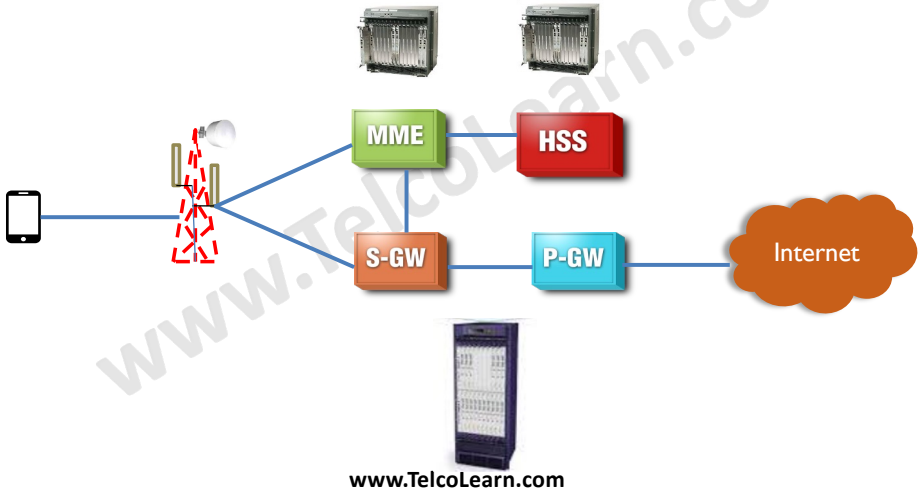
EPC Limitation 4 - Hardware Based Architecture



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5G Core Network Principles

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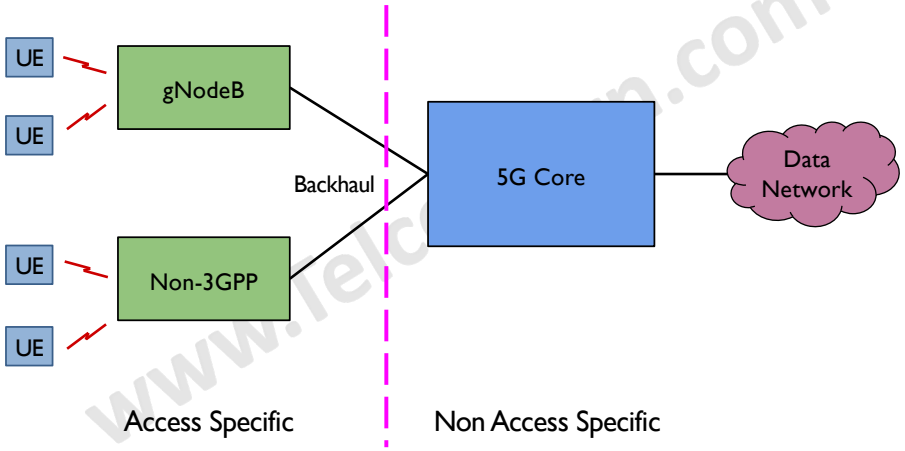
Core in 5G Networks



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Key Functions of (5G) Core Networks

- Authentication of users
- Subscriber database
- Connectivity to the Data Network (Operators/External)
- Mobility
- Policies
- Billing and charging
- Legal intercept
- Quality of service

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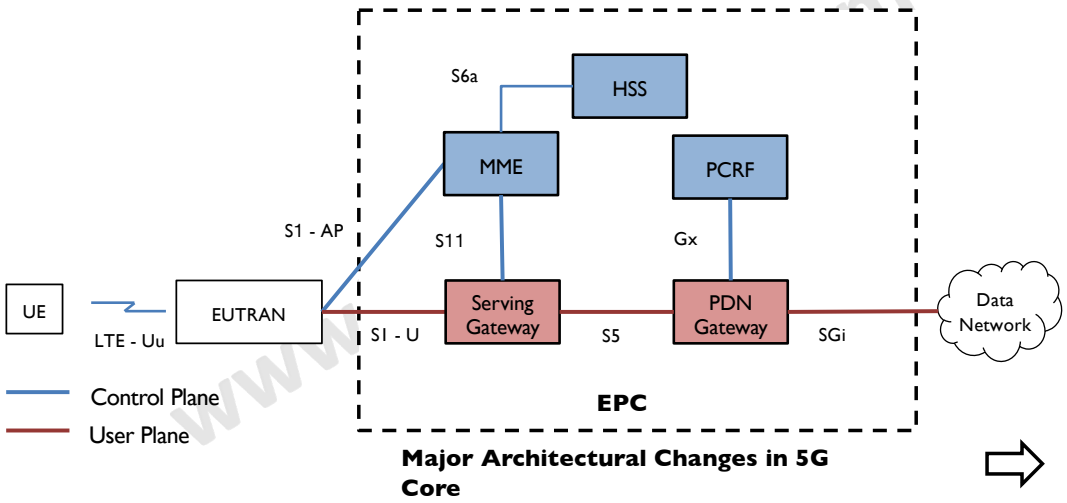
Packet Core in 4G Networks: EPC



Major Architectural Changes in 5G Core

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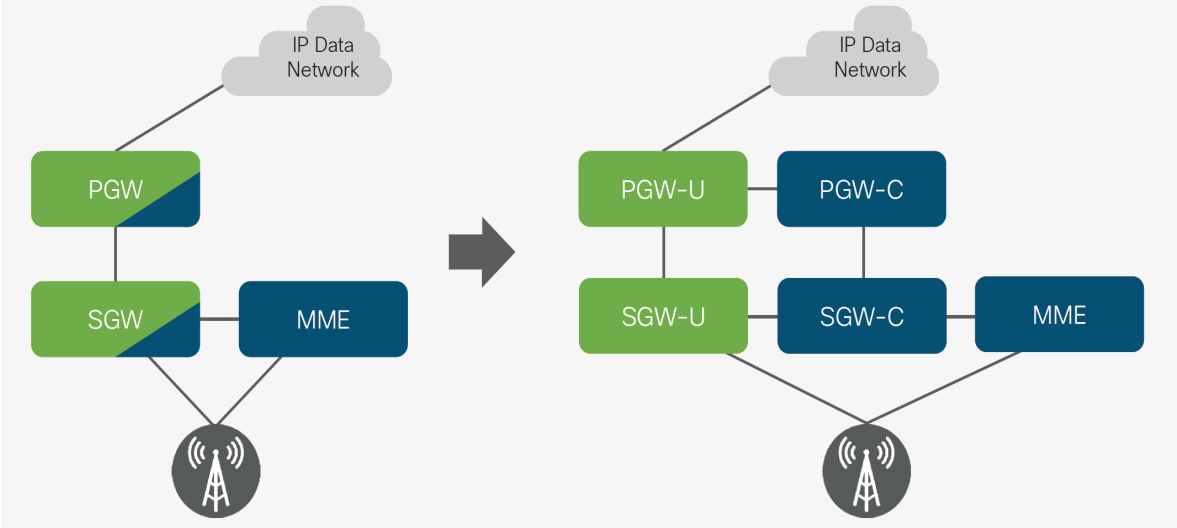
CUPS



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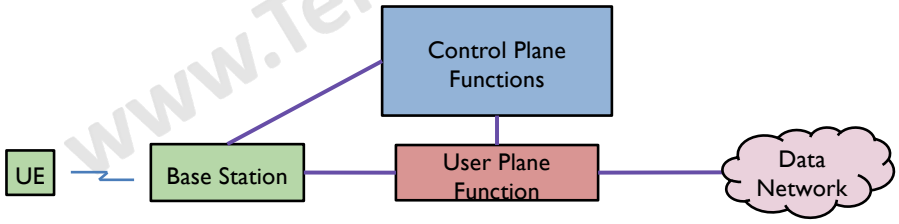
Principle 1: Control and User Plane Separation

- Control user plane separation
  - Control functions totally separated from data plane functions
  - Independent scaling and provisioning
  - Data plane can move closer to user for low latency



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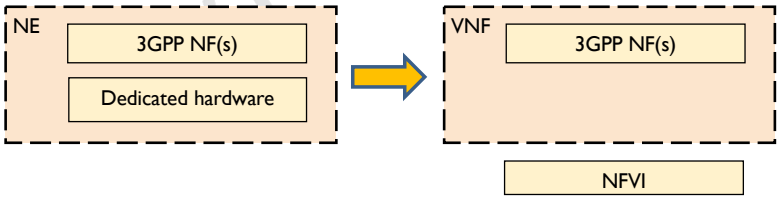
Principle 2: Virtualise the Functions

- Network Function Virtualization (NFV)
  - Decouple network function from hardware
    - Develop as Virtual Network Functions i.e. software functions
    - COTS hardware
  - Stateless, scale on demand
  - Design to run on a cloud (VMs/Containers etc)



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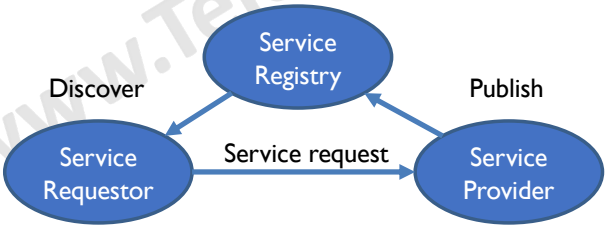
Principle 3: Service Based

- Service Based Architecture (SBA)
  - Control plane components talk over HTTP
  - Network functions as a suite of Services - RESTful APIs
  - Making the network function stateless
  - Protocol based signaling -> API/Service based signaling



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Other Demands on 5G Core

- Slicing
- Elasticity - Scalable NFs and flexible deployments
- Resiliency - Ex. Ability to restart after failure
- Service continuity - Continuity after failures or migration
- Energy efficient - Ex. VNF in sleep state
- Access agnostic core (Supports both 3GPP and Non-3GPP Networks)
- Unified authentication framework
- Network exposure (multiple domains/verticals)

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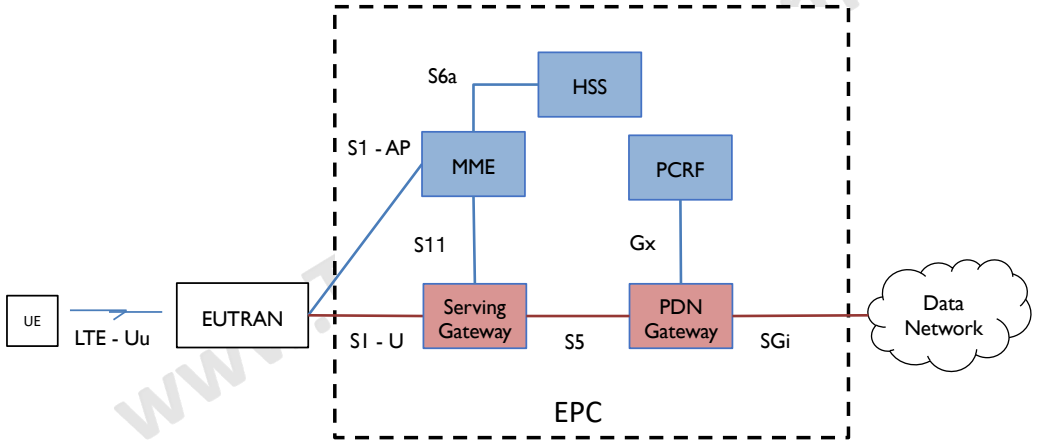
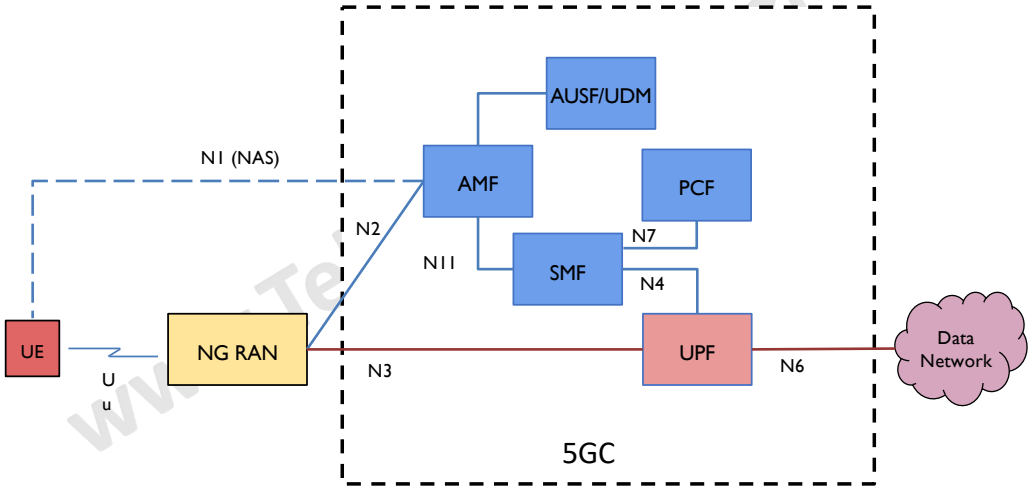
5G Core Evolutions

Evolution From 4G to 5G Core: EPC

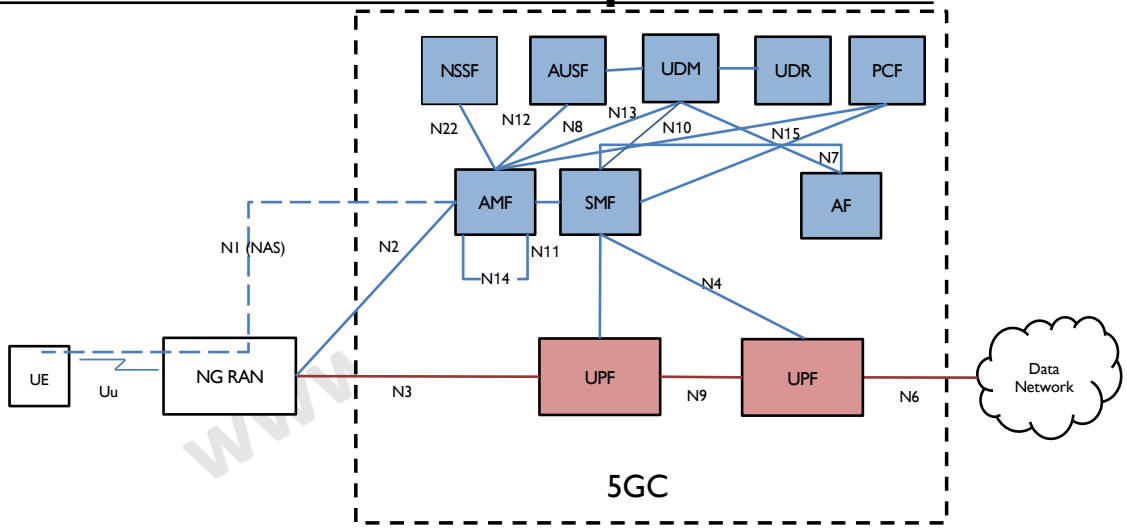


Evolution From 4G to 5G Core: 5G Core



5G Core Network Interfaces and Functions

5G Core - Ref Point Representation



Ref Point interfaces 1/2

Name	Network Functions
N1	Interfaces between UE and the AMF.
N2	Interfaces between (R)AN and the AMF.
N3	Interfaces between (R)AN and the UPF.
N4	Interfaces between SMF and the UPF.
N6	Interfaces between UPF and a Data Network.
N9	Interfaces between two UPFs.
N5	Interfaces between PCF and an AF.
N7	Interfaces between SMF and the PCF.
N8	Interfaces between UDM and the AMF.
N10	Interfaces between UDM and the SMF.
N11	Interfaces between AMF and the SMF.
N12	Interfaces between AMF and AUSF.
N13	Interfaces between UDM and Authentication Server function the AUSF.
N14	Interfaces between two AMFs.
N15	Interfaces between PCF and the AMF in the case of non-roaming scenario, PCF in the visited

Ref Point interfaces 2/2

Name	Network Functions
N16	Interfaces between two SMFs, (in roaming case between SMF in the visited network and the SMF
N17	Interfaces between AMF and 5G-EIR.
N18	Interfaces between any NF and UDSF.
N22	Interfaces between AMF and NSSF.
N23	Interfaces between PCF and NWDAF.
N24	Interfaces between PCF in the visited network and the PCF in the home network.
N27	Interfaces between NRF in the visited network and the NRF in the home network.
N31	Interfaces between NSSF in the visited network and the NSSF in the home network.
N32	Interfaces between SEPP in the visited network and the SEPP in the home network.
N33	Interfaces between NEF and AF.
N34	Interfaces between NSSF and NWDAF.
N35	Interfaces between UDM and UDR
N36	Interfaces between PCF and UDR.
N37	Interfaces between NEF and UDR
N40	Interfaces between SMF and the CHF.
N50	Interfaces between AMF and the CBCF.

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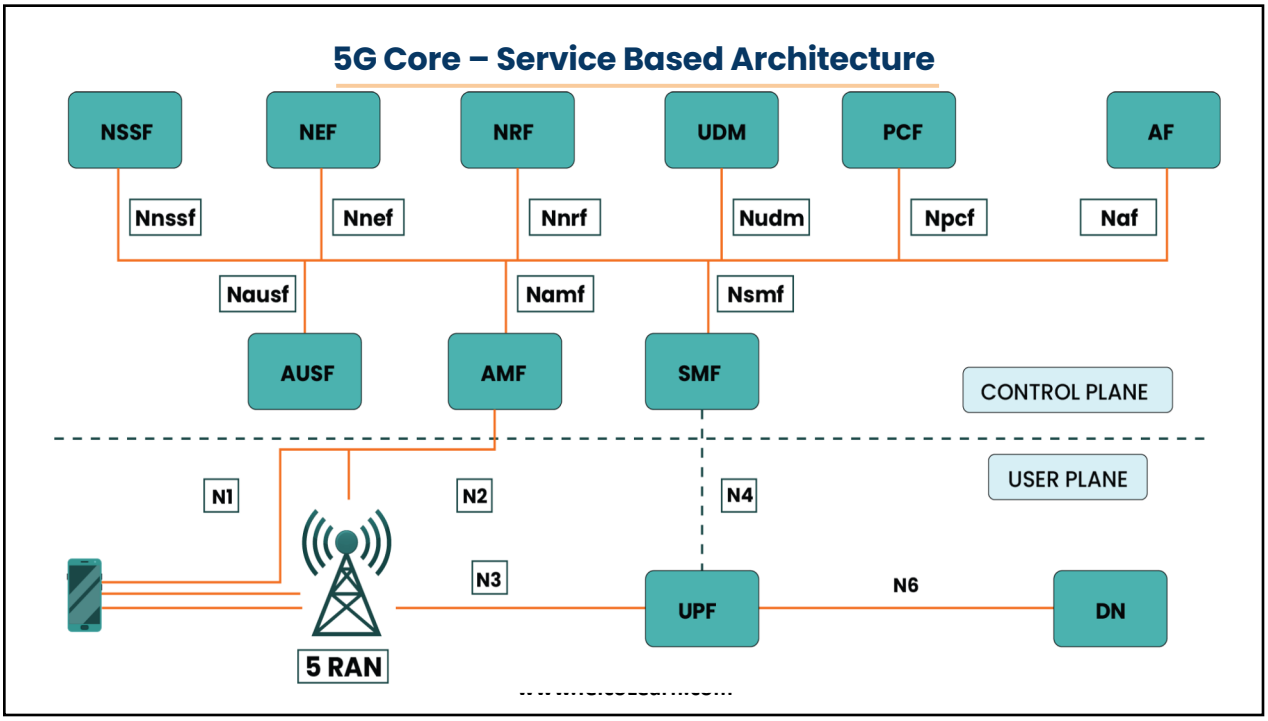

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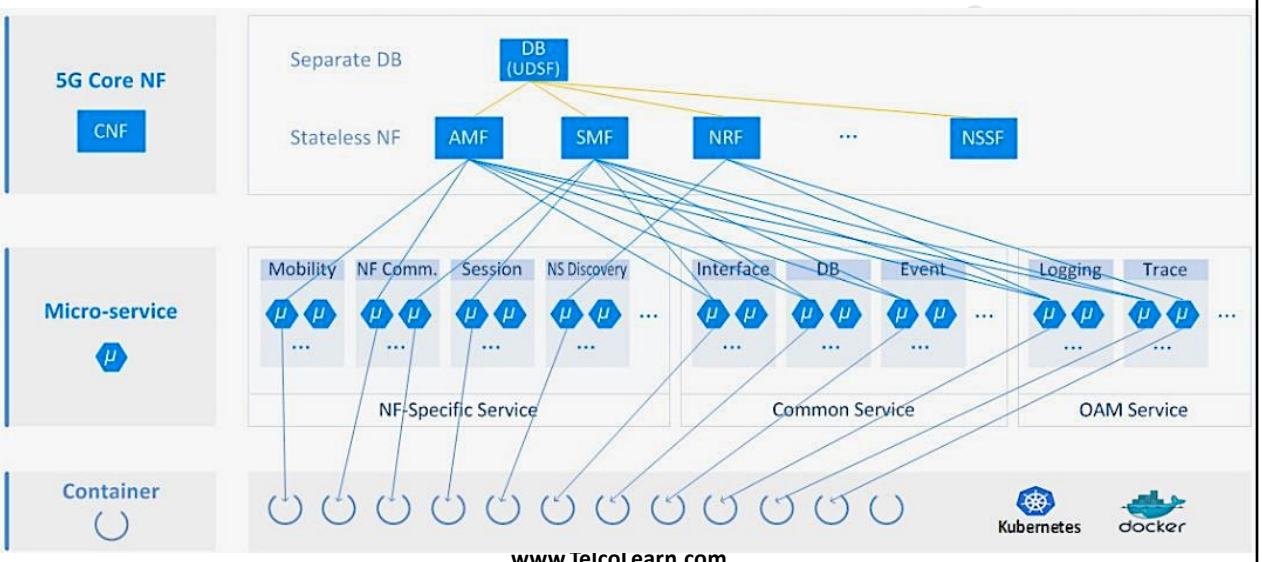
5G Core Cloud Native Architecture



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5G Core Network Functions

AMF	Access and Mobility Management	CHF	Charging Function
AUSF	Authentication Server Function	UPF	User Plane Function
PCF	Policy Control Function	UDM	Unified Data Management
NSSF	NW Slice Selection Function	UDSF	Unstructured Data Storage
NEF	Network Exposure Function	NWDAF	Network Data Analytics
NRF	Network Repository Function	AF	Application Function
SMF	Session Management Function	UDR	Unified Data Repository

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SBA Interfaces

Interface	NF
Namf	AMF
Nsmf	SMF
Nnef	NEF
Npcf	PCF
Nudm	UDM
Naf	AF
Nnrf	NRF
Nnssf	NSSF
Nausf	AUSF
Nudr	UDR
Nudsf	UDSF
N5g-eir	5G-EIR
Nnwdaf	NWDAF

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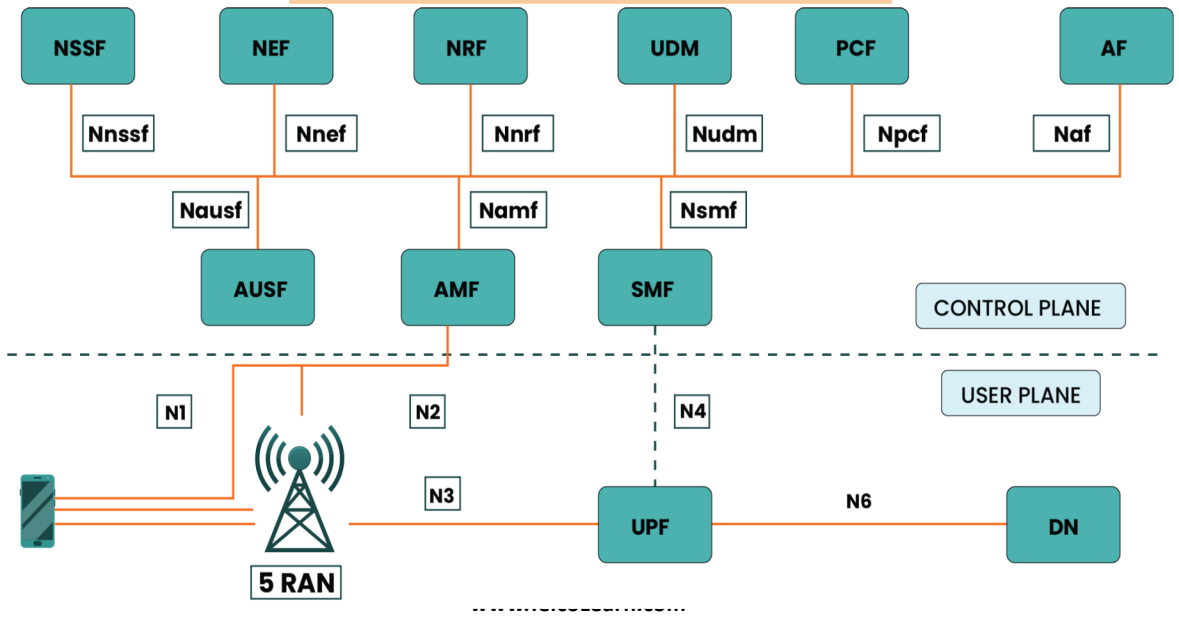
5G Core – Service Based Architecture



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New Radio

- 5G NR (New Radio) is a new Radio Access Technology (RAT) designed to be the global standard for the air interface of 5G networks.
- Technical details are provided by the 3GPP specification 38 series.
- In 2015, the study of NR within 3GPP started and the first specification was published by the end of 2017.

New Radio

- 5G NR uses two frequency ranges:

• Frequency Range1 - FR1 (410 MHz -7.125 GHz)
  - Bands numbered from 1 to 255
  - Earlier referred as Sub 6 Ghz
  - FR1 supports both FDD and TDD bands

• Frequency Range2 - FR2 (24.250 -52.600 GHz) soon to be extended to 114.25 GHz
  - Bands numbered from 257 to 511
  - Commonly referred to as mm Wave
  - FR2 bands are TDD bands

AMF (Access and Mobility Management Function)

- It performs operations like Mobility Management, Registration Management, Connection Management, etc.
- For UE connection, it acts as a single-entry point.
- AMF selects the corresponding SMF for managing the user session context, based on the service requested by the customer.
- When compared with 4G EPC, it's functionalities resembles with MME of 4G Network.

SMF (Session Management Function)

- It performs operations like
  - Session management
  - IP address allocation & management for UE
  - User plane selection
  - QoS & policy enforcement for Control Plane used for Service registration/discovery/establishment
- Its functionalities resemble with SGW-C (Control Plane), MME, and PGW-C (Control Plane) of 4G Network, when compared with 4G EPC.

UPF (User Plane Function)

- Maintains PDU Session, Performs packet routing & forwarding, Packet inspection, Policy enforcement for User plane, QoS handling, etc.
- It's functionalities resemble with SGW-U (Serving Gateway User Plane function) and PGW-U (PDN Gateway User Plane function) of 4G Network, when compared with 4G EPC.

AUSF (Authentication Server Function)

- It allows the AMF to authenticate the UE.
- When compared with 4G EPC, it's functionalities resemble with HSS/AAA Server of 4G Network.

NSSF (Network Slice Selection Function)

- It maintains a list of the operator defined network slice instances.
- Based on the subscription information stored in UDM, AMF authorizes the use of network slices.
- Based on the service requirements, it can also query NSSF to authorize access to a Network slice.
- NSSF redirects the traffic to an intended network slice.

NEF (Network Exposure Function)

- It exposes services and resources over APIs within and outside the 5G Core.
- With the help of NEF, 3rd party applications can also access the 5G services.
- Other core networks can also be exposed using NEF.

NRF (NF Repository Function)

- It maintains the list of available network function instances and their profiles.
- To enable distinct network functions to find each other via APIs, it performs service registration and discovery.
- Example:
  - When UE tries to access a service type served by the SMF, AMF discovers the SMF which is registered to NRF.

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NRF (NF Repository Function)

- Any authorized customer can access the services offered via registered network functions (Producers), since network functions are connected via service message bus in SBA.

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PCF (Policy Control Function)

- It supports policy control framework, applying policy decisions, accessing subscription information, etc to govern the Network behavior.
- When compared with 4G EPC, it's functionalities resembles with PCRF of 4G Network.

Unified Data Management (UDM)

- It performs operations like user identification handling, subscription management, user authentication, access authorization for operations like roaming, etc.
- When compared with 4G EPC, it's functionalities resemble with HSS/AAA Server of 4G network.

Unified Data Repository (UDR)

- It is central repository where data can be stores which includes
  - Subscription Data
  - Policy Data
  - Exposure Data
  - Any Application specific Data

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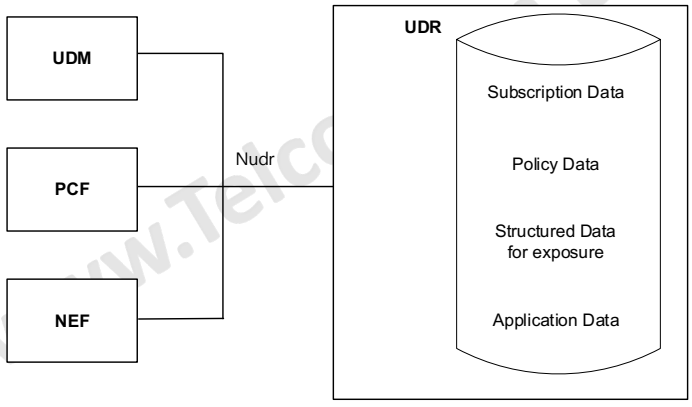
Unified Data Repository (UDR)



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AF (Application Function)

- It performs operations like, interacting with PCF for policy control, accessing network exposure function for retrieving resources, exposing services to end users, etc.
- It's functionalities resembles with AF of 4G network, when compared with 4G EPC.

PCF (Policy Control Function)

- To govern the network behavior, it supports policy control framework, applying Policy decisions, accessing subscription information, etc.
- It's functionalities resembles with PCRF of 4G Network, when compared with 4G EPC.

5G Deployment Options

- Interworking with previous generations provide multiple options for the deployment of the 5G networks.
- In this case, there are two types of deployments for the radio access networks called standalone and non-standalone.
- The core can be either 5GC or EPC.

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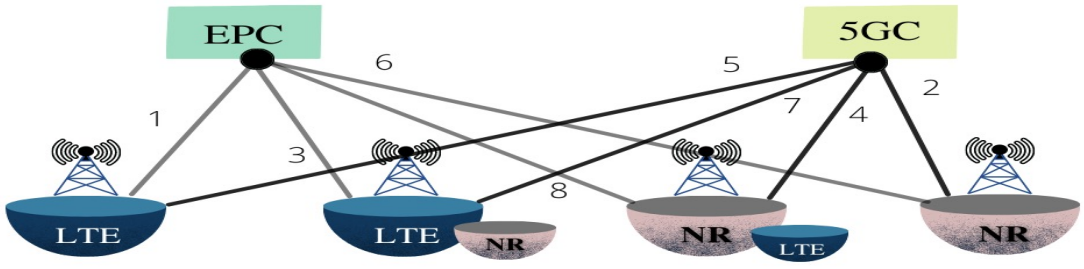
5G Evolution and co-existence with 4G



EPC:Evolved Packet Core LTE:Long Term Evolution NR:New Radio Interface and Radio Access

Access Network	LTE only	NR only	LTE with NR for data only	NR with LTE for data only
EPC core Network	Option 1 (=4G)	Option 6 (Disregarded)	Option 3	Option 8 (Disregarded)
5 GC core Network	Option 5	Option 2	Option 7	Option 4

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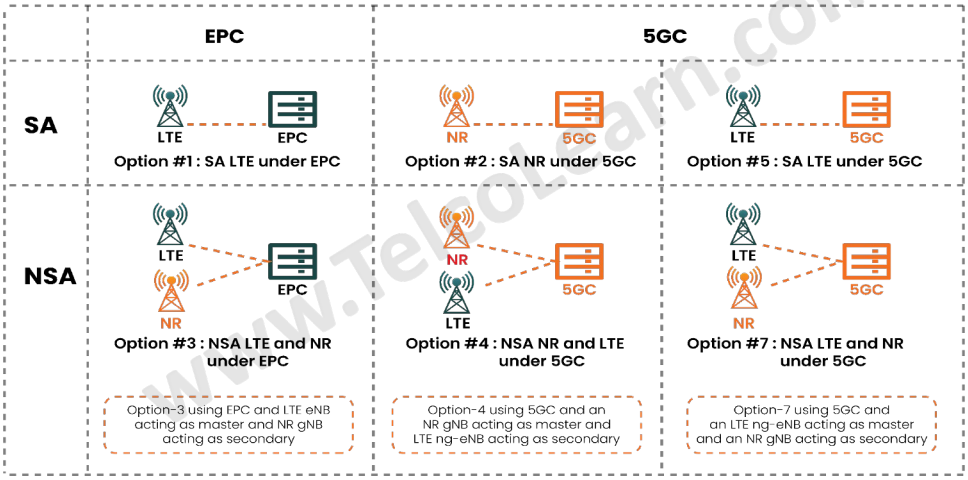
5G Network Deployment - Options

Six deployment options in both SA and NSA modes



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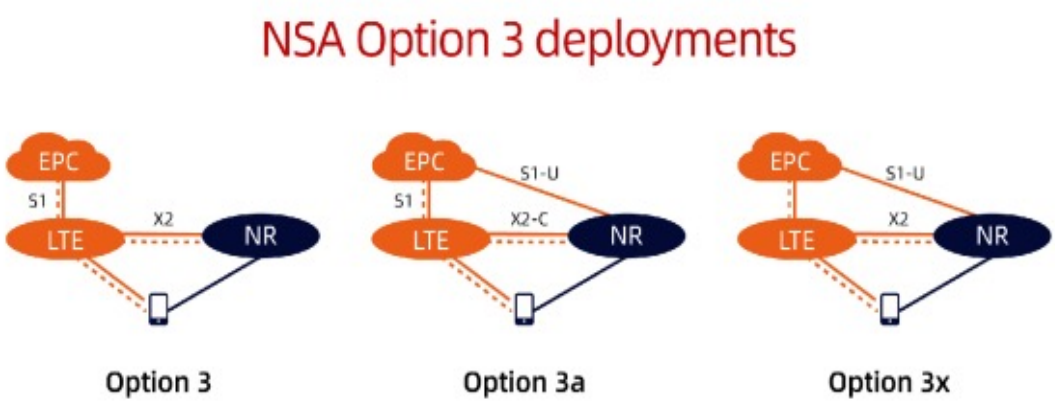
Option 3/3a/3x



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5G Terminologies &Identities

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Terminologies 5G vs 4G

4G	5G
IMEI	PEI
MSISDN	GPSI
IMSI	SUPI/SUCI
MME	AMF
SGW+PGW Control Plane	SMF
SGW+PGW User Plane	UPF
HSS	UDM +AUSF + UDR
PCRF	PCF
Bearer	QoS Flow
PDN Connection	PDU session
PDN	DN
APN	DNN

While very similar but they are not exactly same

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S-NSSAI Single Network Slice Selection Assistance Information

- **Usage -** Identification of a Network Slice is done via the S-NSSAI.
- **S-NSSAI comprises of** -
  - Slice/Service Type (SST)- refers to the expected Network Slice behavior in terms of features and services
  - Slice Differentiator (SD) - an optional information that complements the Slice/Service type(s) to differentiate amongst multiple Network Slices of the same Slice/Service type.
- **Relevance -** The S-NSSAI signaled by the UE to the network, assists the network in selecting a particular Network Slice instance.
- The S-NSSAI may be associated with a PLMN (e.g., PLMN ID) and have network-specific values or have standard values
- **Standardized SST Values**

Slice/Service type	SST value	Characteristics.
eMBB	1	Slice suitable for the handling of 5G enhanced Mobile Broadband.
URLLC	2	Slice suitable for the handling of ultra- reliable low latency communications.
MIoT	3	Slice suitable for the handling of massive IoT.

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PLMN and DNN

Public Land Mobile Network ID - (PLMN ID)

- A Public Land Mobile Network is uniquely identified by its PLMN identifier.
- PLMN-Id consists of Mobile Country Code (MCC) and Mobile Network Code (MNC).

DNN - Data Network Name

- **Usage -** Data Networks are specifically identified using a DNN Like APN in earlier access technologies
- **Relevance -** A slice specific network function(s) (e.g. SMF) within the NSI are selected by the AMF during a PDU session establishment based on the S-NSSAI and DNN included in the PDU session establishment request and other information

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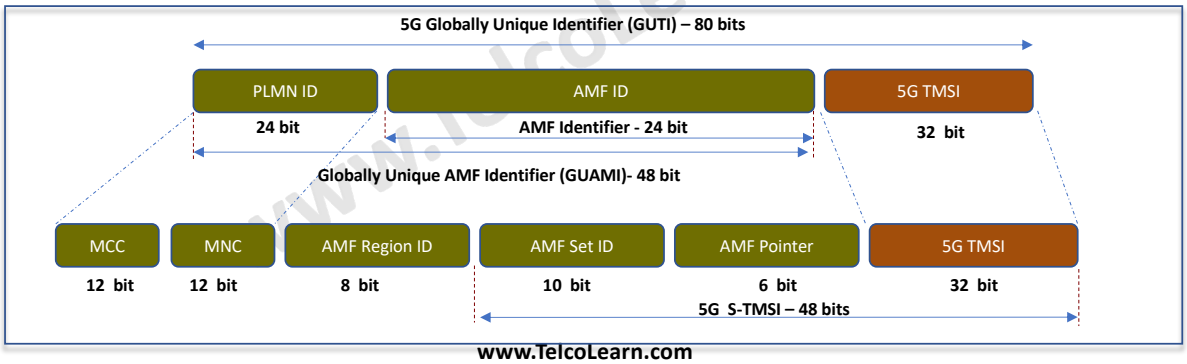
Globally Unique Temporary Identifier - GUTI

Globally Unique Temporary Identifier - GUTI

- AMF is the in-charge to assign (any time) GUTI to an UE and it is common to both 3GPP and non-3GPP access. - 5G GUTI = GUAMI + 5G TMSI
- Relevance -
  - The purpose of the 5G-GUTI is to provide an unambiguous identification of the UE that does not reveal the UE or the user's permanent identity in the 5G System (5GS).
    It also allows the identification of the Access and Mobility Management Function (AMF) and network.



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GUAMI and 5G S-TMSI

GUAMI - Globally Unique AMF ID

- GUAMI is used to uniquely identify an AMF within a 5G network.
- It is comprised of the MCC (Mobile Country Code), MNC (Mobile Network Code), AMF Region ID, AMF Set ID and AMF Pointer.
- **Relevance -** It is used to route the initial NAS message from NG-RAN to AMF. When UE provides GUAMI in RRC connection along with very first NAS message, RAN prepares and sends the received the NAS message to the right AMF node

5G-S-TMSI

- The 5G-S-TMSI is the shortened form of the 5G-GUTI to enable more efficient radio signaling procedures (e.g. paging and Service Request).
- For paging purposes, the mobile is paged with the 5G-S-TMSI.
- The 5G-S-TMSI shall be constructed from the AMF Set ID, the AMF Pointer and the 5G-TMSI

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User Level Identities

Permanent Equipment Identifier (PEI) -

- Defined for the 3GPP UE accessing the 5G System
- The PEI can assume different formats for different UE types and use cases. The UE shall present the PEI to the network together with an indication of the PEI format being used.
- If the UE supports at least one 3GPP technology, it must be allocated a PEI in the IMEI format.

Subscription Permanent Identifier (SUPI)

- Globally unique identifier assigned to each UE
- Usage - To uniquely identify the subscribers in 5g system
- Relevance - Provisioned in UDM/UDR, It is based on IMSI (TS 23003) + Network specific identifier (TS 22261). In this way, UE can present its IMSI to the network (EPC) in inter-working scenarios.

Subscription concealed Identifier (SUCI)

- SUCI is a privacy preserving identifier containing the concealed SUPI.
- Relevance - UE generates this by concealing SUPI with the public key of the home operator

For more detailed info, Please visit 3GPP TS23.501, Clause 5.9

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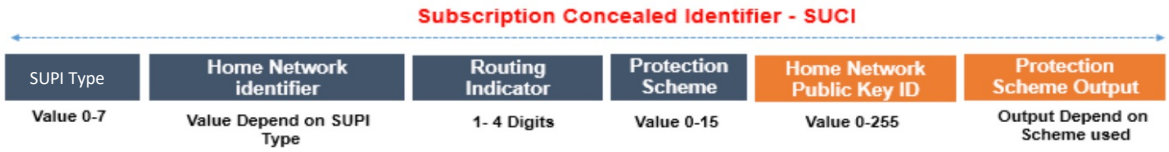
SUCI



SUPI Type: 3 bit, consisting in a value in the range 0 to 7.
It identifies the type of the SUPI concealed in the SUCI.
The following values are defined-

•0: IMSI
•1: Network Access Identifier (NAI)
•2 to 7: spare values for future use.

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NG and Xn Interface

NG Interface

- **RAN UE NGAP ID -**
  - Assigned By NG
  - Usage - to uniquely identify the UE over the NG interface within gNB.
  - Relevance - stored in AMF and AMF includes it in all UE associated NGAP signaling.
- **AMF UE NGAP ID -**
  - Assigned By AMF
  - Usage - to uniquely identify the UE within the AMF
  - Relevance - stored in NG-RAN and NG-RAN includes it in all UE associated NGAP signaling

Xn Interface

- **Old NG-RAN node UE XnAP ID -**
  - Assigned By NG-RAN
  - Usage - to uniquely identify the UE over Xn interface within a source NG-RAN node.
  - Relevance - included in all XnAP signaling by target NG-RAN.
- **New NG-RAN node UE XnAP ID -**
  - Assigned By NG-RAN
  - Usage - to uniquely identify the UE over Xn interface within a target NG-RAN node.
  - Relevance - included in all XnAP signaling by source NG-RAN.

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Thank You

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