Migration, Management, and Orchestration for 5G networks

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February 1, 2019

- What will be some of the most important use cases for 5G network slicing in the context of smart cities?

- Are most existing smart city initiatives (Houston, Dallas, Raleigh etc.) well prepared to take advantage of network slicing, or do they need further investment to get their infrastructure up to speed?

- What challenges, if any, can local governments encounter in implementing network slicing in their smart city plans?

Is 5G really here?

- Verizon launched 5G Home service in select areas of Indianapolis, Sacramento, Los Angeles, and Houston (with a maximum data speed of 940 Mbps - 5G Home should run reliably at 300 Mbps).

- *First major ISP to 5G**

- Verizon is using a proprietary communications standard, called 5G TF, separate from industry standard 5G New Radio (NR) developed by 3GPP.

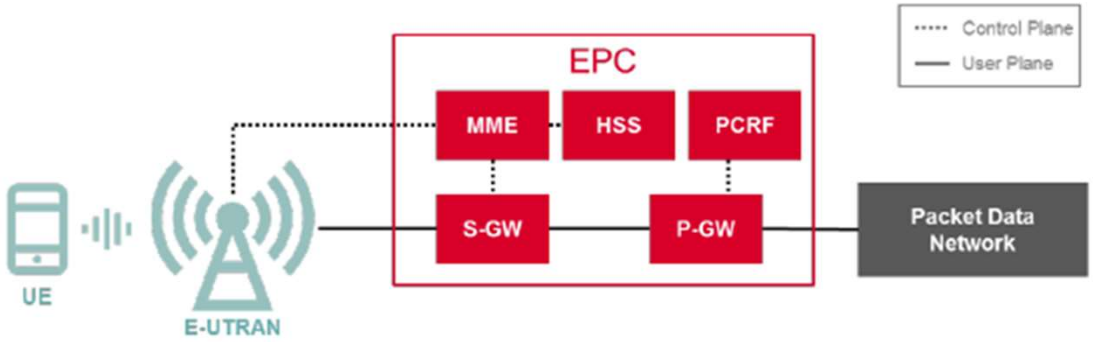
- Verizon is halting 5G Home's rollout until it can switch everything over from 5G TF to the industry-backed 5G NR - completely replace the 5G hardware it has deployed for 5G Home.

4G to 5G:
5G Network Deployment Options

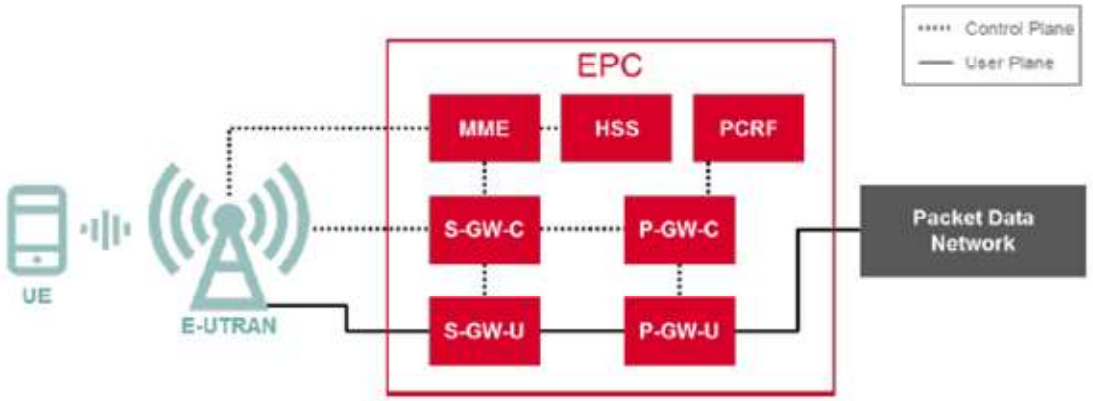
- As with the previous generations, 3GPP is defining both a new 5G core network (5GC) as well as a new radio access technology called 5G “New Radio” (NR).
  - Previous generations required both access and core network of the same generation to be deployed (e.g. Evolved Packet Core (EPC) and LTE together formed a 4G system).
  - With 5G it is possible to integrate elements of different generations in different configurations:
    - Standalone (SA) using only one radio access technology
    - Non-Standalone (NSA) combining multiple radio access technologies

https://www.gsma.com/futurenetworks/wp-content/uploads/2018/04/Road-to-5G-Introduction-and-Migration_FINAL.pdf

EPC



EPC architecture

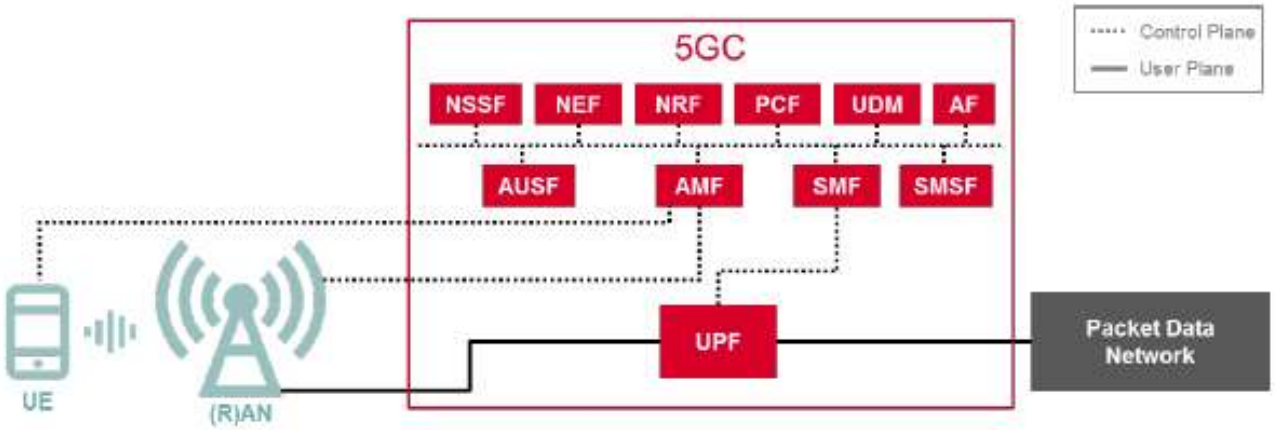


EPC Architecture with CUPS (Control and User Plane Separation)

CUPS allows operators to flexibly place the separated control and user plane functions to support diverse deployment scenarios without affecting the overall functionality.

- With the NFV technologies, the mobile network functions can be virtualized and hosted in a cloud environment.
  - The physical boundary between traditional EPC network elements such as MME, SGW, and PGW will be blurred with virtualization and software. This promotes the 5GC to be redesigned and become open and flexible (“cloud native”).

5GC



Service Based Architecture of 5G Core

UPF: User Plane Function

AF: Application Function

- AMF: Access and Mobility Management Function
- AUSF: Authentication Server Function
- NEF: Network Exposure Function
- NRF: Network Repository Function
- NSSF: Network Slice Selection Function
- PCF: Policy Control Function
- SMF: Session Management Function
- SMSF: SMS (Short Message Service) Function
- UDM: User Data Management

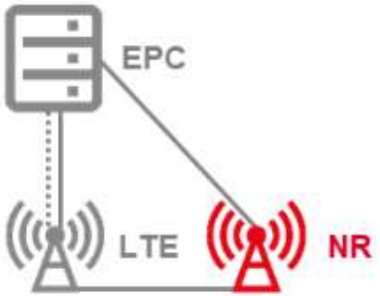
Feature	EPC (4G Core)	5GC (5G Core)
Access Network interface	S1 with per UE assigned MME & SGW (in case of CUPS: single SGW-C and multiple SGW-U) & multiple PDN GWs ePDG and TWAG for non-3GPP access	N2/3 common to all access with per UE assigned AMF & multiple N3 to UPFs
Procedures	Access dependent procedures.	Unified registration, authentication, session management for 3GPP, non-3GPP access (including untrusted, trusted WLAN and in Rel 16 also fixed access), Common N1/N2/N3 for 3GPP and non-3GPP access, enabling seamless mobility
Network slicing	Single slice per UE with multiple PGW	E2E multiple slices per UE with shared AMF, slicing aware RAN and per slice SMF/UPF (potentially slice specific PCF, NRF, etc.)
QoS model	QCI based bearers	QoS flow based framework, including reflective QoS support
Cloud native	Possible but node based (box driven)	Native support for cloud based deployment with service based architecture and service-based interfaces within 5GC CP; Definition of NF services
Local applications	Support LIPA/SIPTO based deployment	Support for edge computing. Application influence on traffic routing.
Session/service continuity	Supports full IP address preservation for centralized GW or break before make solution for local GW (LIPA/SIPTO); service continuity with 2G/3G PS and SRVCC	Improved Session model including different Session and Service Continuity modes. Support for concurrent (e.g. local and central) access to a data network. No service continuity with 2G/3G PS and no support of SRVCC.
Policy framework	Support SM/QoS based policies	Unified Policy framework for Access and mobility control, QoS and charging enforcement, policy provisioning in the UE; introducing NWDA (Network Data Analytics) for data analytics support.
Services supported	SMS over NAS over 3GPP access, IMS services over 3GPP access and non-3GPP access, LCS, MPS, MCPTT, mobile broadband	SMS over NAS (including over Non- 3GPP), support of IMS services over 3GPP access and non-3GPP access, LCS, MPS, MCPTT, mobile broadband
Support for RRC INACTIVE state	Support not specified	Support for RRC inactive (RRC state machine includes 3 states: RRC IDLE, INACTIVE, CONNECTED)

Overview of SA and NSA Options

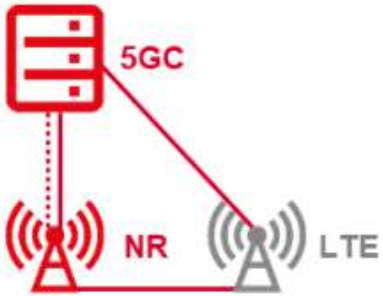
Standalone LTE under EPC (option 1)

Standalone NR under 5GC (option 2).

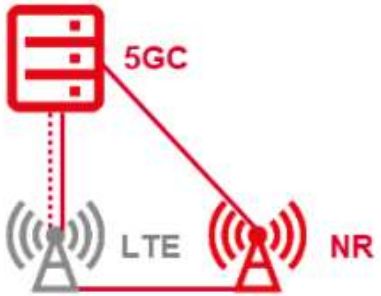
Standalone LTE under 5GC (option 5)



Non-standalone LTE and NR under EPC (option 3)



Non-standalone NR and LTE under 5GC (option 4).



Non-standalone LTE and NR under 5GC (option 7)

- In SA, the 5G NR or the evolved LTE radio cells and the core network are operated alone. NR or evolved LTE radio cells are used for both control plane and user plane.

- The standalone option is a simple solution for operators to manage and may be deployed as an independent network using normal inter-generation handover between 4G and 5G for service continuity.

- Three variations of SA:
  - Option 1 using EPC and LTE eNB access (i.e. as per current 4G LTE networks);
  - Option 2 using 5GC and NR gNB access;
  - Option 5 using 5GC and LTE ng-eNB access

- In NSA, the NR radio cells are combined with LTE radio cells using dual-connectivity to provide radio access and the core network may be either EPC or 5GC depending on the choice of operator.

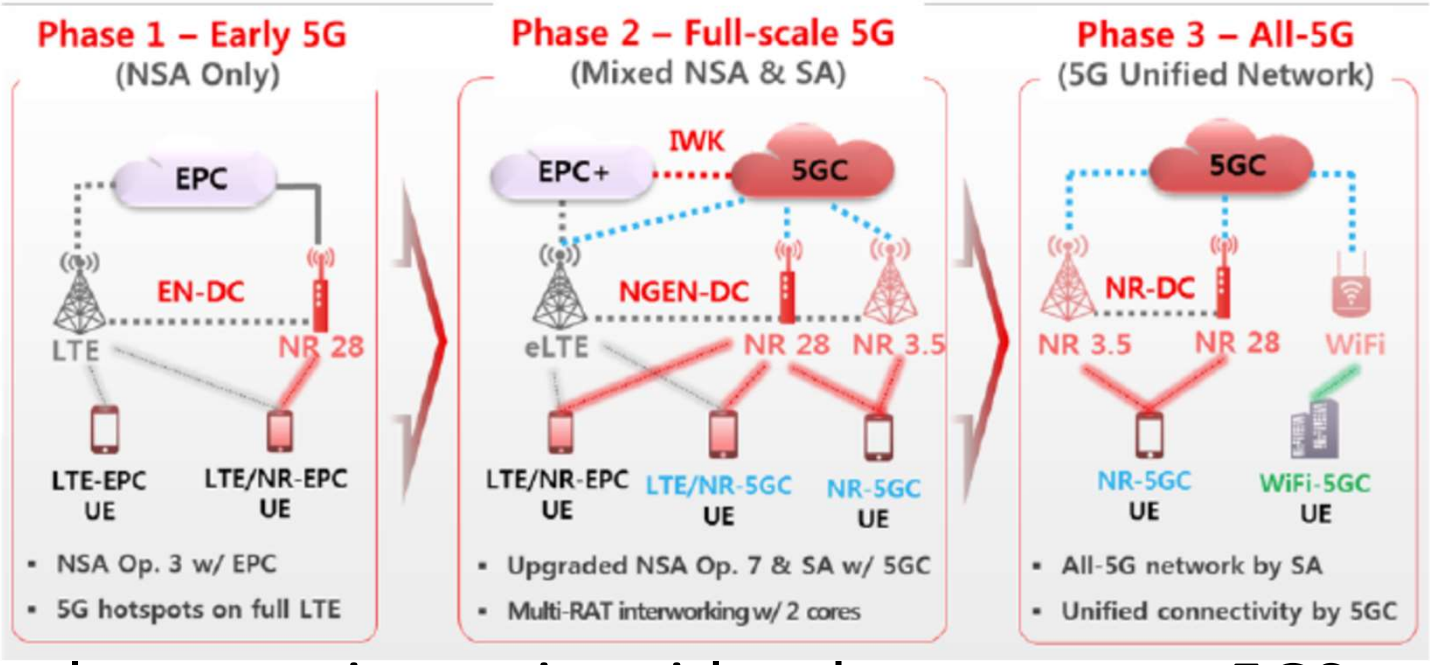
- Operators can leverage existing 4G deployments, combining LTE and NR radio resources with existing EPC and/or that wish new 5GC to deliver 5G mobile services.
  - This solution will require tight interworking with the LTE RAN. The end user experience will be dependent on the radio access technology(ies) used.

- Three variations of NSA:
  - Option 3 using EPC and an LTE eNB acting as master and NR en-gNB acting as secondary;
  - Option 4 using 5GC and an NR gNB acting as master and LTE ng-eNB acting as secondary;
  - Option 7 using 5GC and an LTE ng-eNB acting as master and an NR gNB acting as secondary.

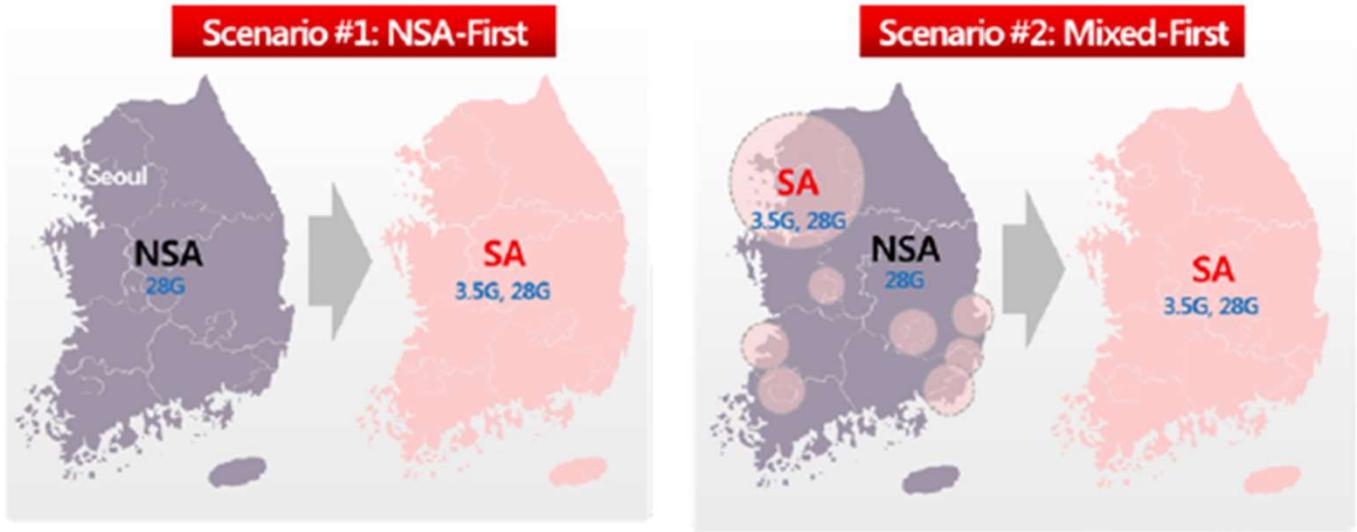
Dual Connectivity: Operation where a given UE consumes radio resources provided by at least two different network points (e.g. NR access from gNB and LTE access from eNB).

5G Migration

- 5G can be introduced either in standalone mode (on-
- It
  - EPC
  - plans to migrate in mid-or long-term to 5GS.



- Two possible scenarios for nationwide 5G m



  - A): le
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    major cities + NSA in other areas -> nationwide SA: Traffic-driven deployment.

3GPP specification work is done in Technical Specification Groups (TSGs) and Working Groups (WGs)

- There are three TSGs, each of which consists of multiple WGs:
  - **RAN** (Radio Access Network): RAN specifies the UTRAN and the E-UTRAN
  - **SA** (Services and Systems Aspects): SA specifies the service requirements and the overall architecture of the 3GPP system. It is also responsible for the coordination of the project. SA is composed of six WGs.
  - **CT** (Core Network and Terminals): CT specifies the core network and terminal parts of 3GPP. It includes the core network – terminal layer 3 protocols. It is composed of five WGs.

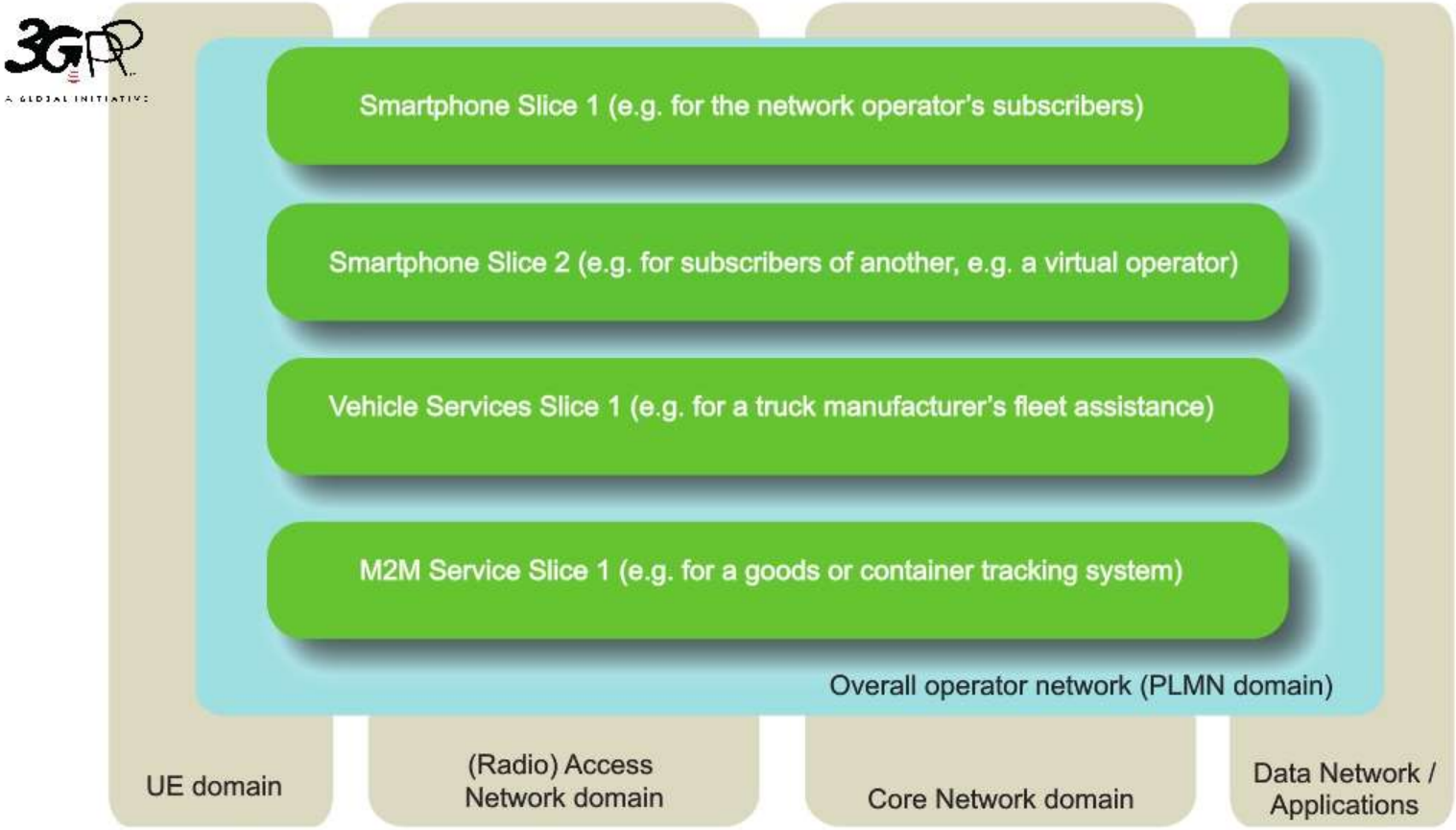
Network Slicing

- Earlier system architectures enabled what was typically a single deployment of a PLMN to provide all features, capabilities and services required for all wanted usage scenarios.

- Much of the capabilities and features provided by the single, common deployment was in fact required for only a subset of the PLMN's users/UEs.

- Network slicing enables the network operator to deploy multiple, independent PLMNs where each is customized by instantiating only the features, capabilities and services required to satisfy the subset of the served users/UEs or a related business customer needs.

Two network slices for smartphones represent that an operator may deploy multiple network slices with exactly the same system features, capabilities and services, but dedicated to different business segments.

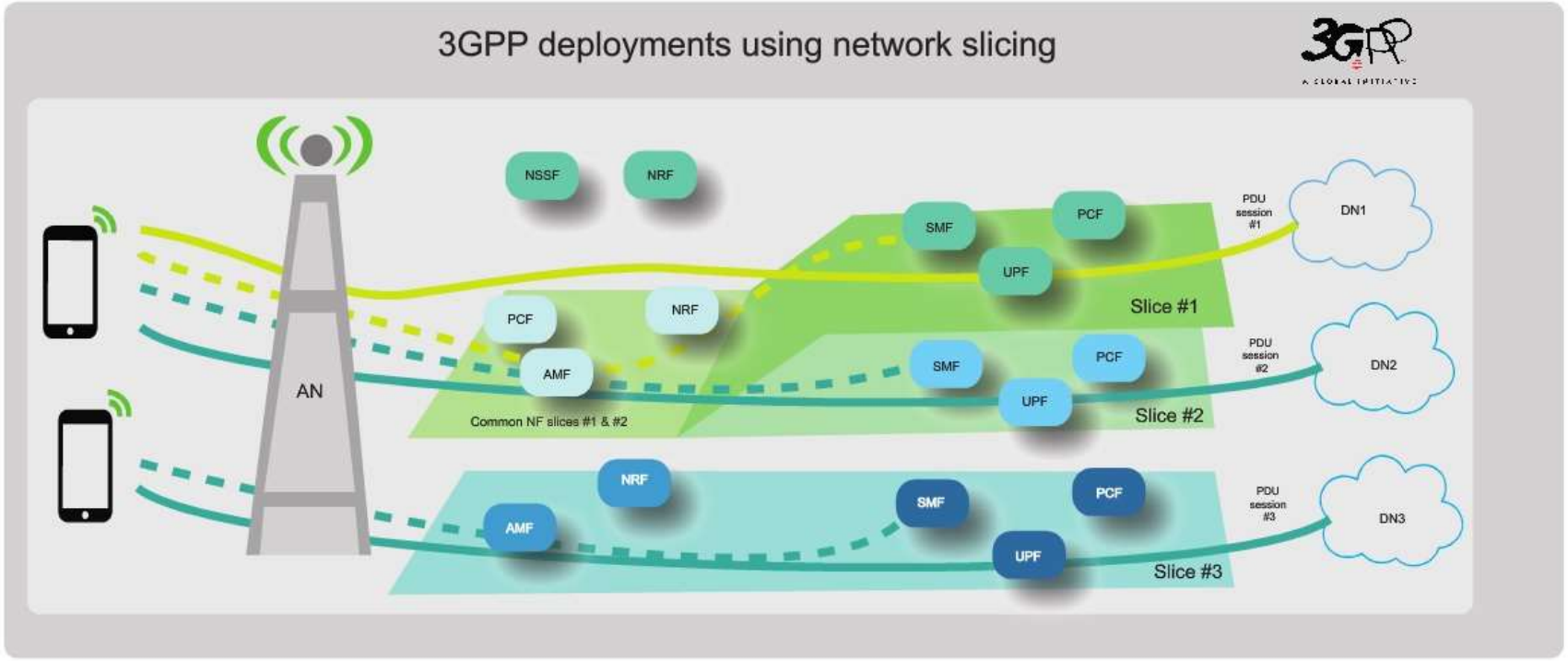


A PLMN deploying four network slices

The other slices represent differentiation between network slices based on features, capabilities and services.

http://www.3gpp.org/ftp/Inbox/Marcoms/flip_brochure/index.html#p=8

* Network slice#3 is a straightforward deployment where all network functions serve a single network slice only.



* A UE receives service from multiple network slices,#1and #2.

Network functions are common for a set of slices, including AMF and related PCF and NRF - a single access control and mobility management instance per UE is responsible for all services of a UE.
The user plane services (data services) can be obtained via multiple, separate network slices - slice#1 provides the UE with data services for Data Network #1,and slice#2 for Data Network #2.

http://www.3gpp.org/ftp/Inbox/Marcoms/flip_brochure/index.html#p=8

5G Networks and Network Slicing

- Management and orchestration of 5G networks and network slicing includes :
  - management concept and architecture, provisioning, network resource model, fault supervision, assurance and performance management, trace management and virtualization management aspects.
- An operator can configure and manage the mobile network to support various types of services enabled by 5G (e.g., eMBB, URLLC, etc.) depending on the different customers' needs.

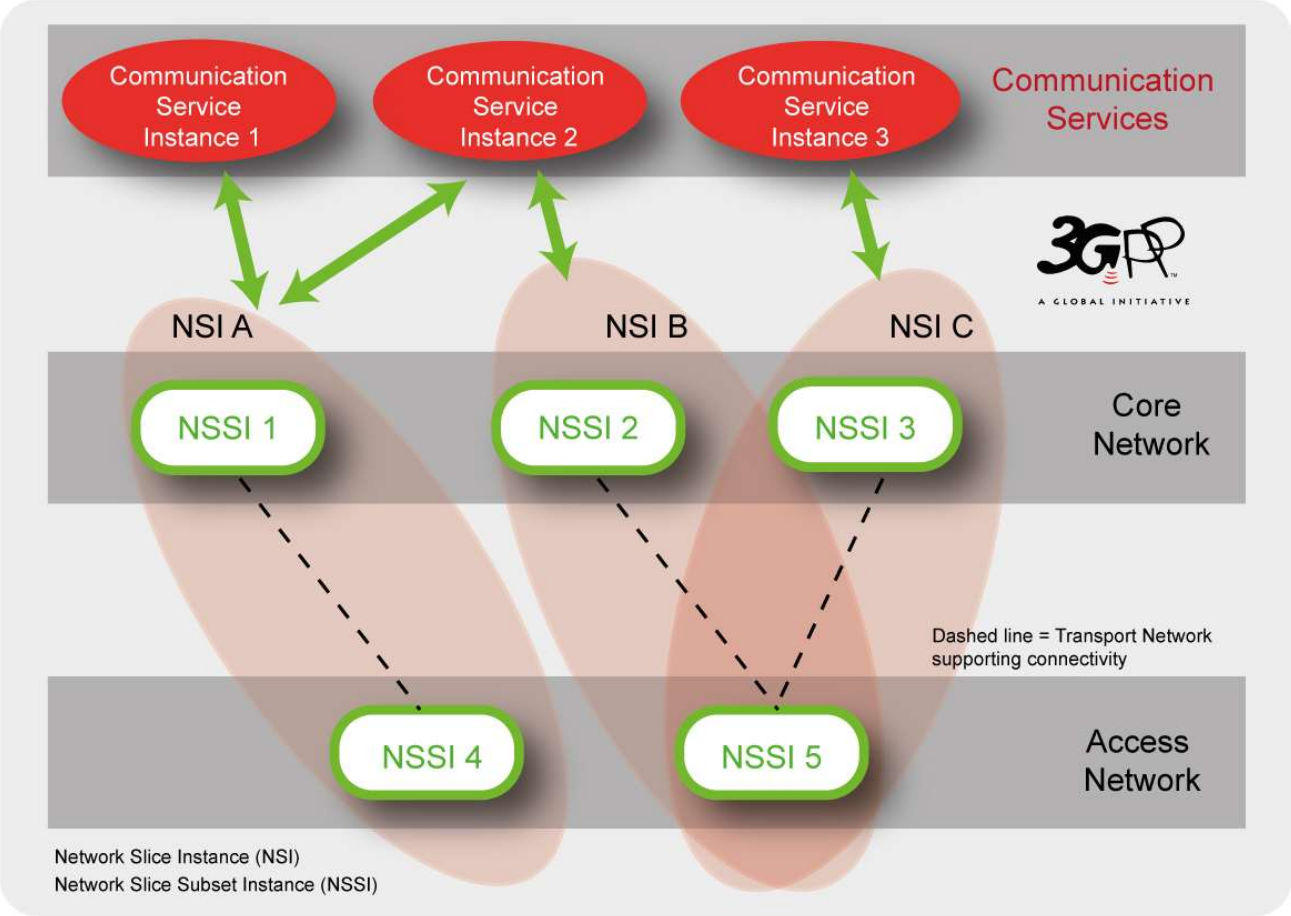
http://www.3gpp.org/NEWS-EVENTS/3GPP-NEWS/1951-SA5_5G

5G Networks and Network Slicing

- Network slicing is about transforming a PLMN from a single network to a network where logical partitions are created, with appropriate network isolation, resources, optimized topology and specific configuration to serve various service requirements.

- As shown below:
  - A variety of communication service instances are provided by multiple Network Slice Instances (NSIs).
  - The different parts of an NSI are grouped as Network Slice Subnets (e.g. RAN, 5GC and Transport) allowing the lifecycle of a Network Slice Subnet Instance (NSSI) to be managed independently from the lifecycle of an NSI.

5G Networks and Network Slicing



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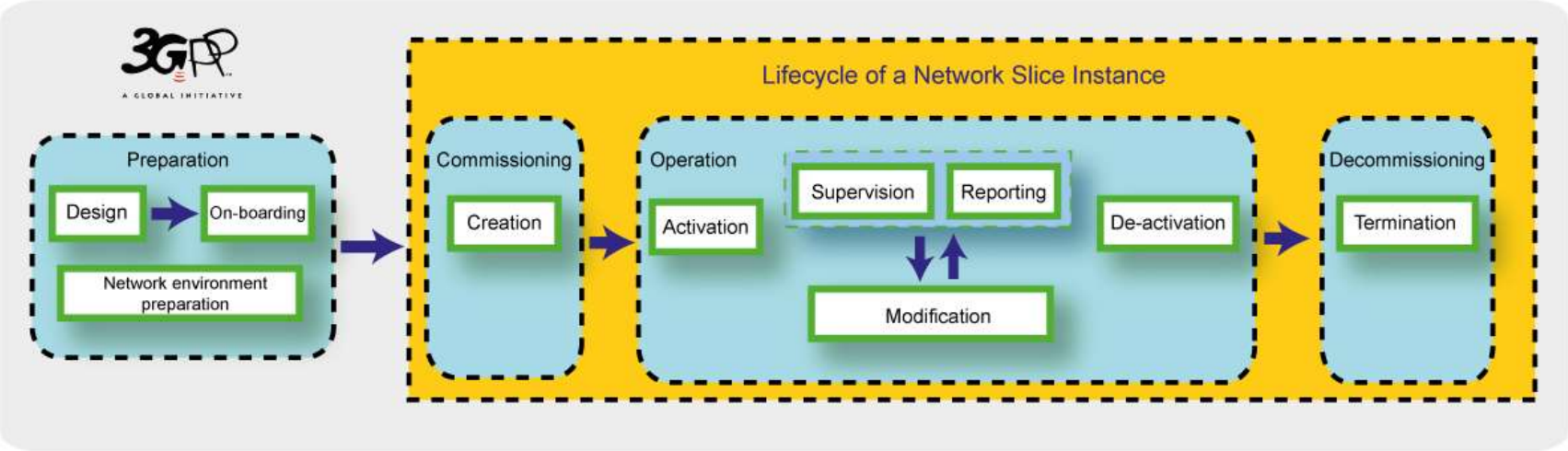
Provisioning of Network Slice Instances

- The management aspects of a network slice instance can be described by the four phases:
  - **Preparation**: in this phase, the network slice instance does not exist. It includes network slice template design, network slice capacity planning, on-boarding and evaluation of the network slice requirements, preparing the network environment and other necessary preparations required to be done before the creation of a network slice instance.
  - **Commissioning**: It involves creation of the network slice instance. All needed resources are allocated and configured to satisfy the network slice requirements. It can include creation and/or modification of the network slice instance constituents.
  - **Operation**: It involves activation, modification and de-activation of a network slice instance. More specifically, it includes the activation, supervision, performance reporting (e.g. for KPI monitoring), resource capacity planning, modification, and de-activation of a network slice instance.
  - **Decommissioning**: It includes decommissioning of non-shared constituents if required and removing the network slice instance specific configuration from the shared constituents. After the decommissioning phase, the network slice instance is terminated and does not exist anymore.

- Provisioning for a network slice subnet instance (NSSI) includes the following operations:
  - Create an NSSI;
  - Activate an NSSI;
  - De-active an NSSI;
  - Modify an NSSI;
  - Terminate an NSSI.

Provisioning of Network Slice Instances



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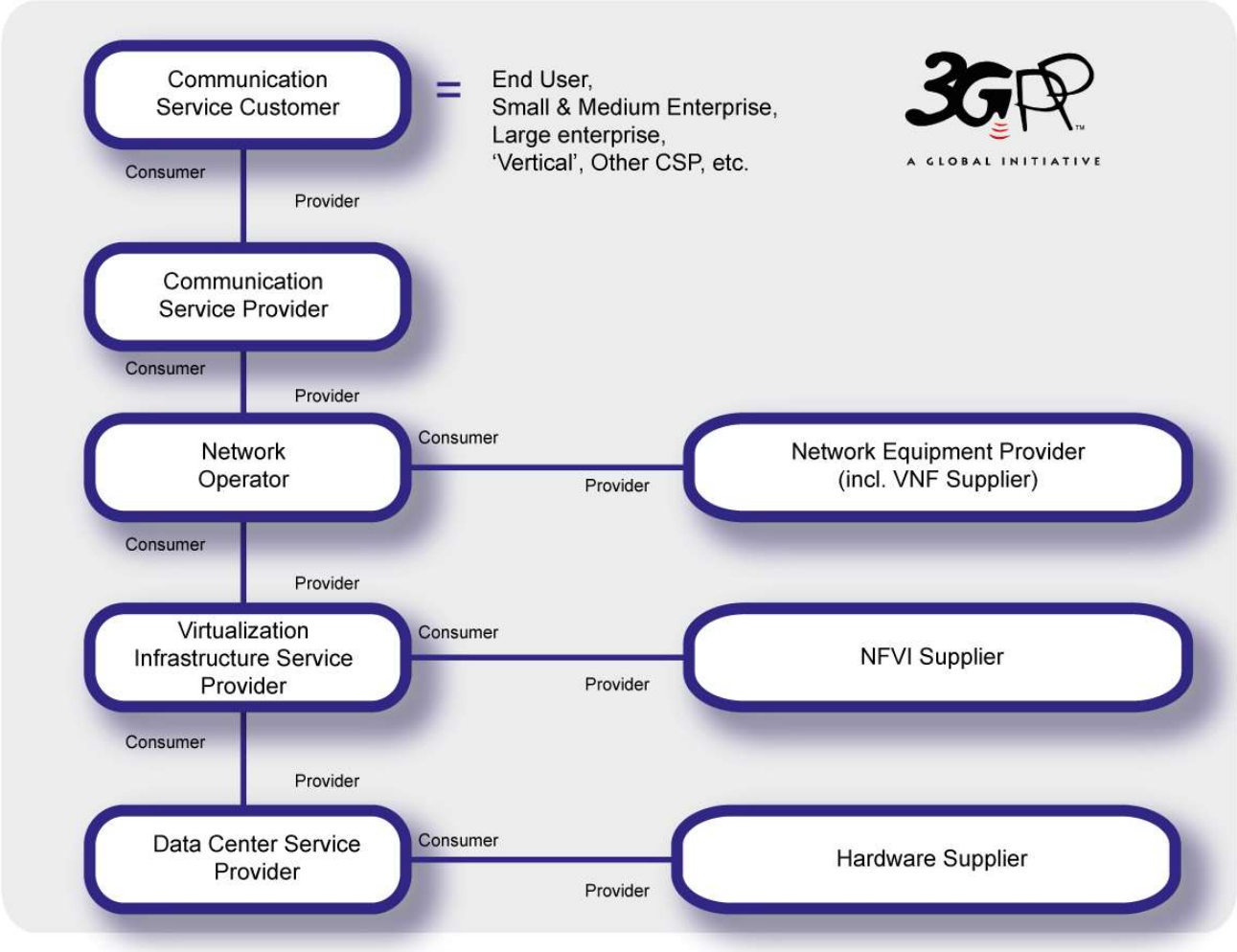
Roles Related to 5G Networks and Network Slicing

- Roles related to 5G networks and network slicing management include:
  - Communication Service Customer, Communication Service Provider (CSP), Network Operator (NOP), Network Equipment Provider (NEP), Virtualization Infrastructure Service Provider (VISP), Data Centre Service Provider (DCSP), NFVI (Network Functions Virtualization Infrastructure) Supplier and Hardware Supplier.
- Depending on actual scenarios:
  - Each role can be played by one or more organizations simultaneously.
  - An organization can play one or several roles simultaneously (for example, a company can play CSP and NOP roles simultaneously).

Roles Related to 5G Networks and Network Slicing



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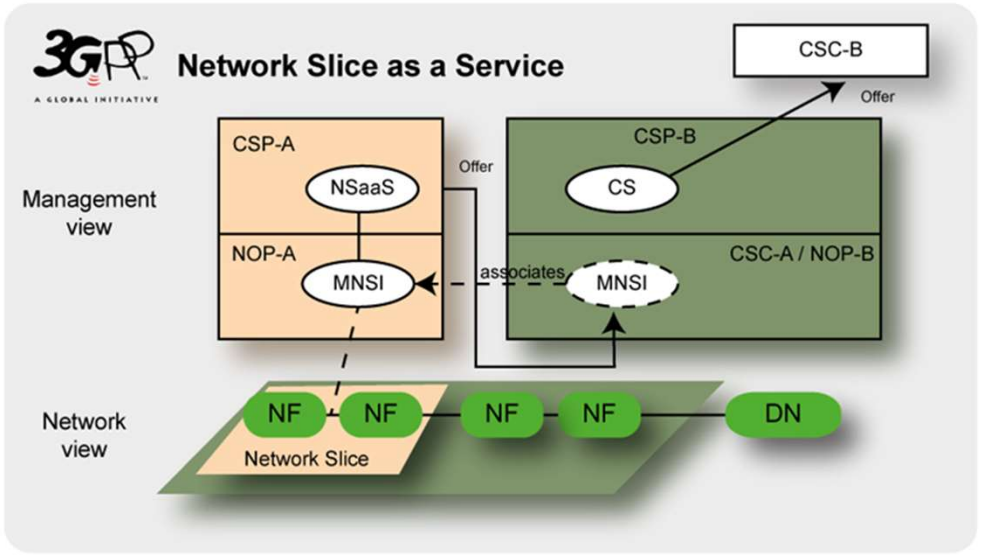
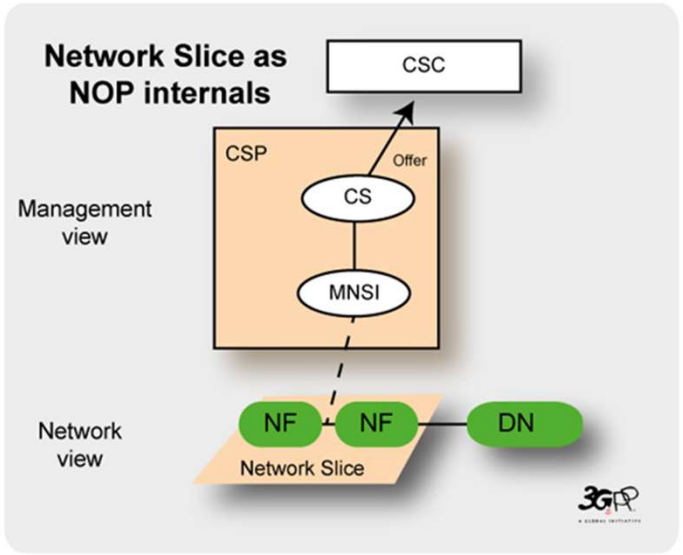
Management models for network slicing

- Network Slice as a Service (NSaaS):
  - NSaaS can be offered by a CSP to its CSC in the form of a communication service. It allows CSC to use and optionally manage the NSI.
  - In turn, this CSC can play the role of CSP and offer their own communication services on top of the NSI.

- Network Slices as NOP internals:
  - Network slices are not part of the CSP service offering and hence are not visible to CSCs. However, the NOP, to provide support to communication services, may decide to deploy network slices, e.g. for internal network optimization purposes.

Management models for network slicing





Managed Network Slice Instance (MNSI)

- New management functions are required to provide an appropriate abstraction level for automation:
  - communication service management function (CSMF),
  - network slice management function (NSMF)
  - network slice subnet management function (NSSMF)

http://www.3gpp.org/NEWS-EVENTS/3GPP-NEWS/1951-SA5_5G

Network Resource Model

- Network Resource Model (NRM) represents the manageable aspects of 5G networks:
  - NRM for the 5G core network (5GC)
  - NRM for 5G radio access network (i.e. NR and NG-RAN).
- 5GC NRM support management of
  - 5GC Network Functions,
  - respective interfaces as well as AMF Set and AMF Region.
- The NR and NG-RAN NRM definitions cover various
  - 5G radio networks connectivity options (standalone and non-standalone radio node deployment options)
  - architectural options (NR nodes with or without functional split)
    - NR node (gNB) is defined to support three functional split options (i.e. non-split option, two split option with CU and DU, three split option with CU-CP, CU-UP and DU)

5G Standards – **How Do We Call This One?**

1G	2G	3G	4G	5G
BS (Base Station)	BTS (Base Transceiver Station)	NB (NodeB)	eNB (evolved NodeB)	gNB (next generation NodeB) but also: en-gNB, ng-eNB, gNB-DU, Ils-gNB-DU ...