5G and 5G Advanced selected Capabilities
to
LFN 5G Super Blueprint

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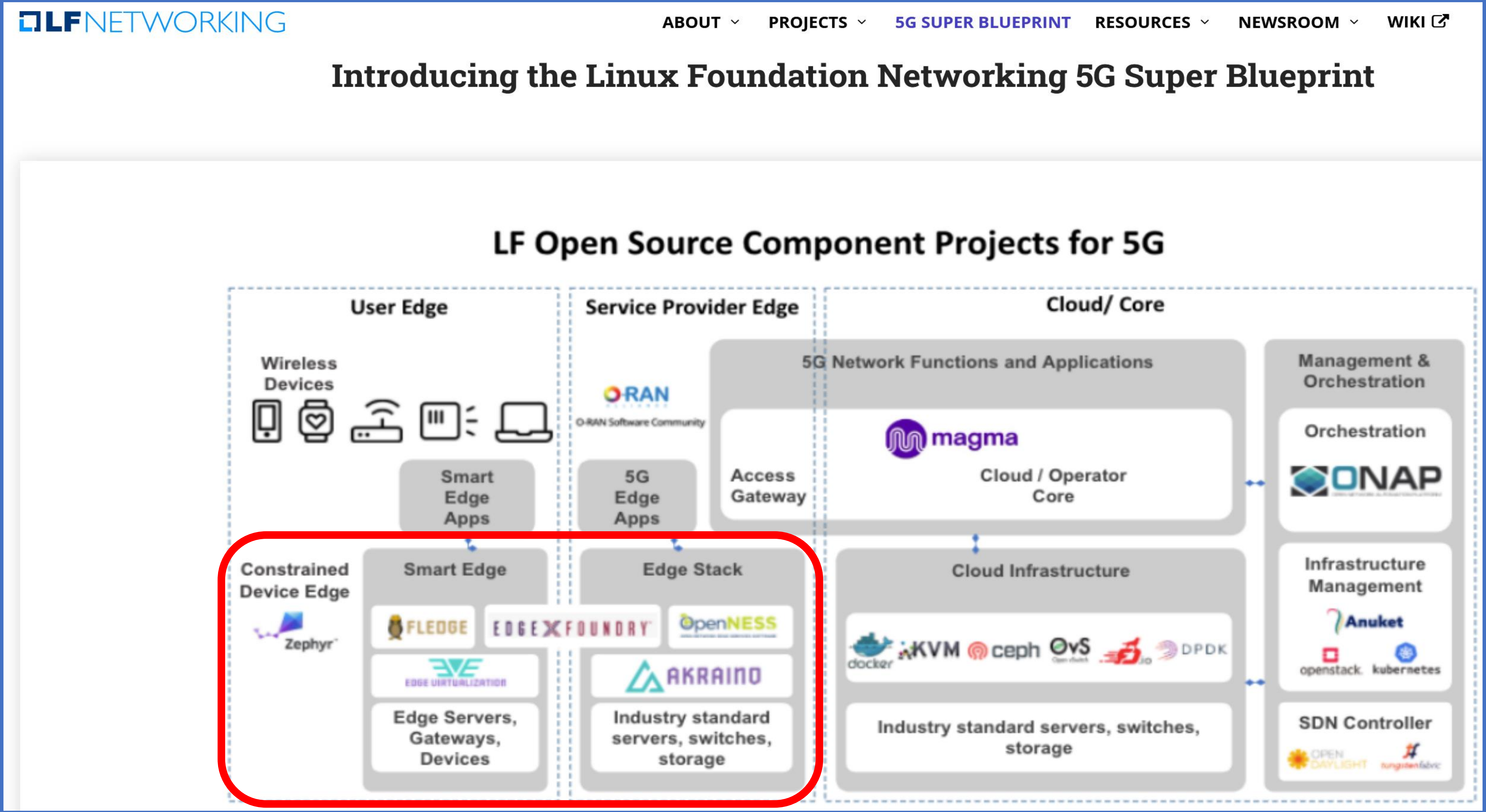
1. & 2. 5G Super Blueprint Remarks & 5G Definition Options

1. 5G Super Blueprint - remarks - 1



1. 5G Super Blueprint - remarks - 2

GSMA

Operator Requirements for 5G Core Connectivity Options

May 2019

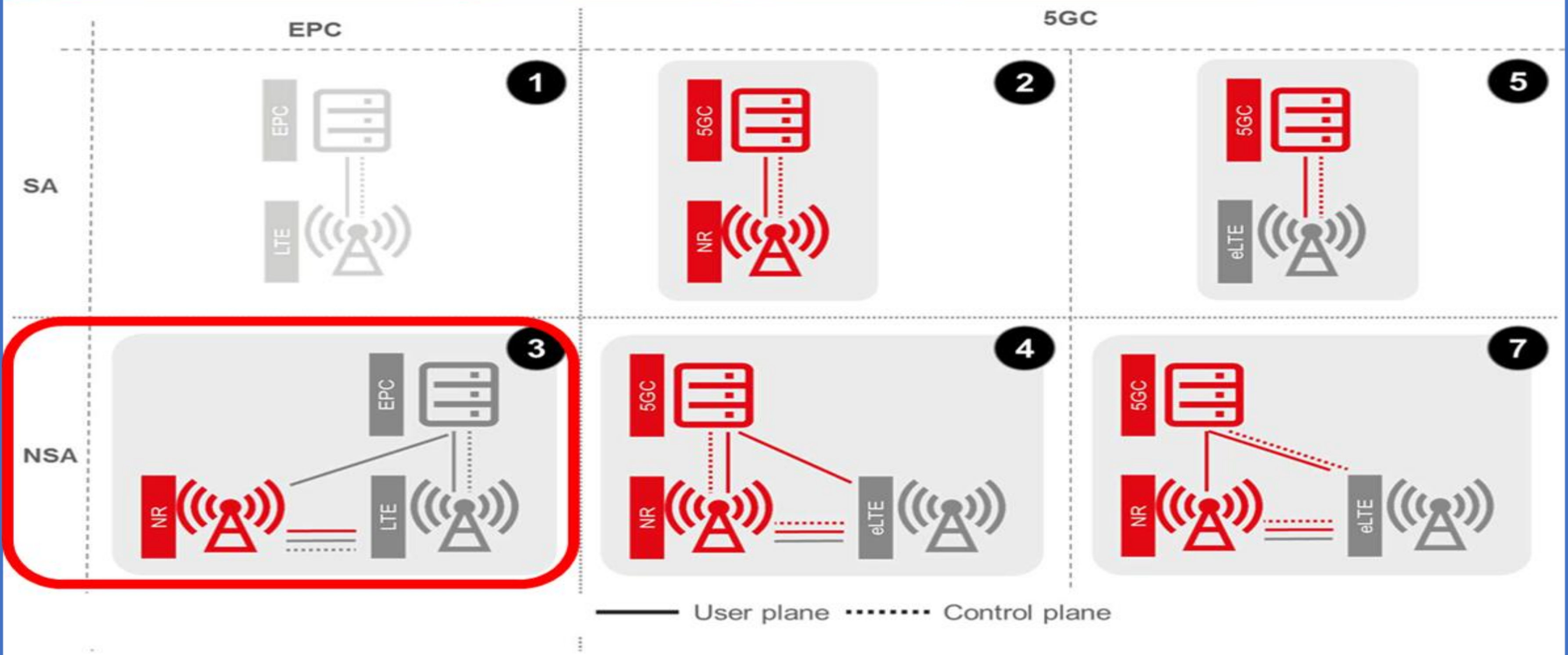


Figure 1: 3GPP defined options for 5G deployment

It is widely expected that Mobile Operators will initially deploy 5G using **Option 3** allowing the re-use of existing EPC Core functionality. **Option 3 has been fully specified in an early drop of 3GPP Release 15.**

1. 5G Super Blueprint - remarks - 3

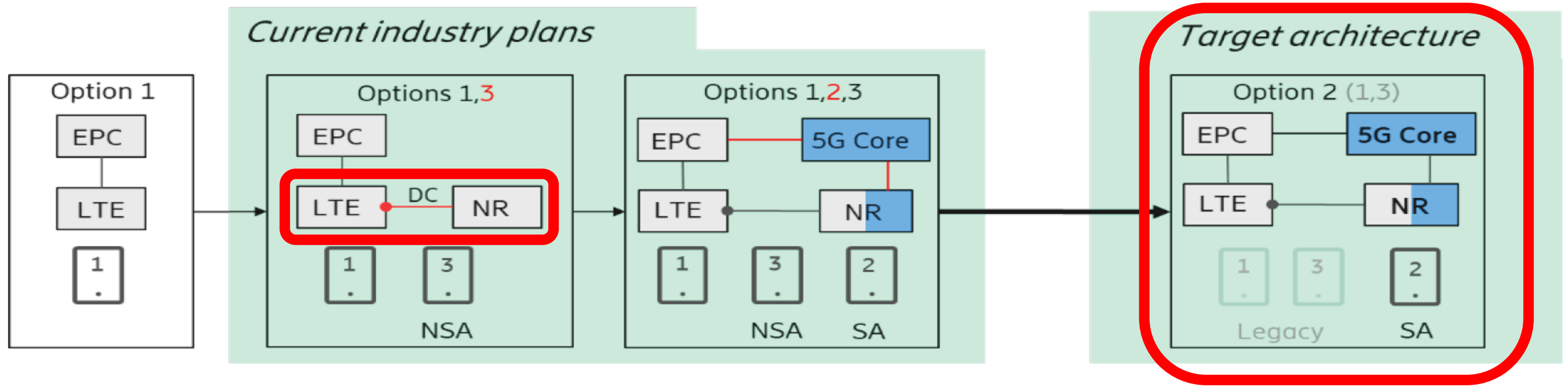


Fig. Migration towards 5G target architecture.

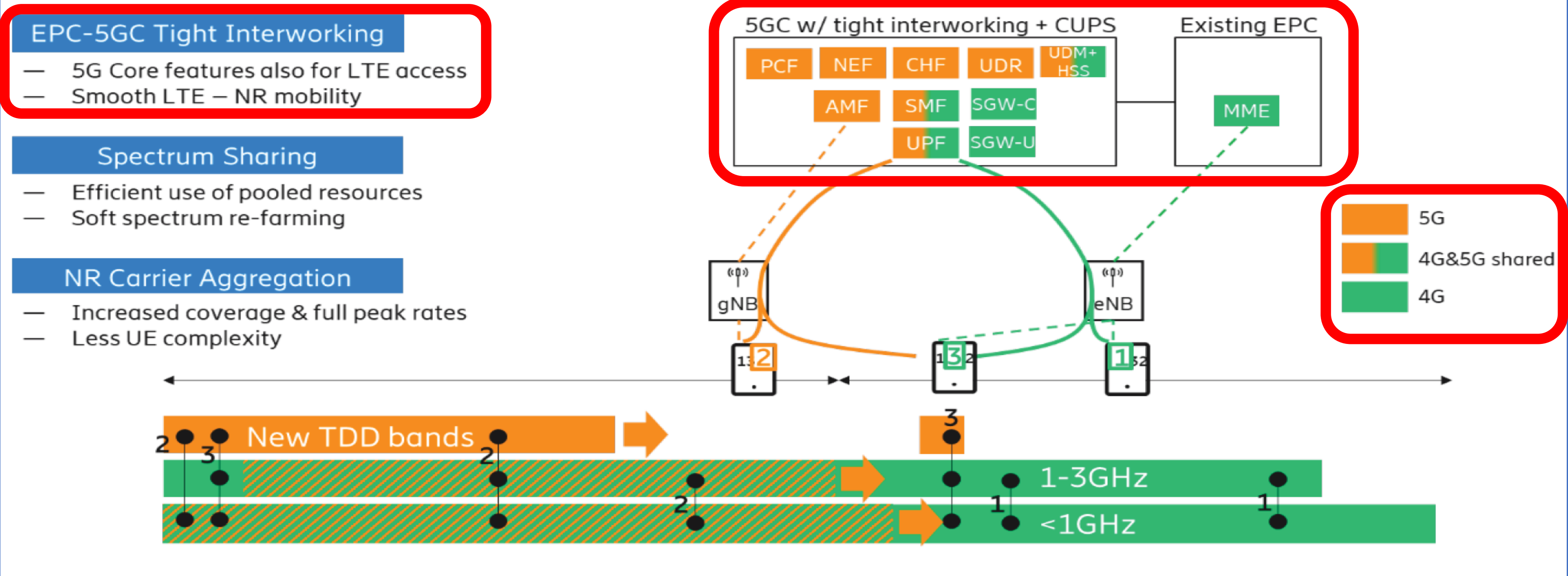


Fig. Migration to 5G using Options 1, 3 and 2.

1. 5G Super Blueprint - remarks - 4

The IAB-node can access the network using either SA mode or EN-DC. In EN-DC, the IAB-node connects via E-UTRA to a MeNB, and the IAB-donor terminates X2-C as SgNB.

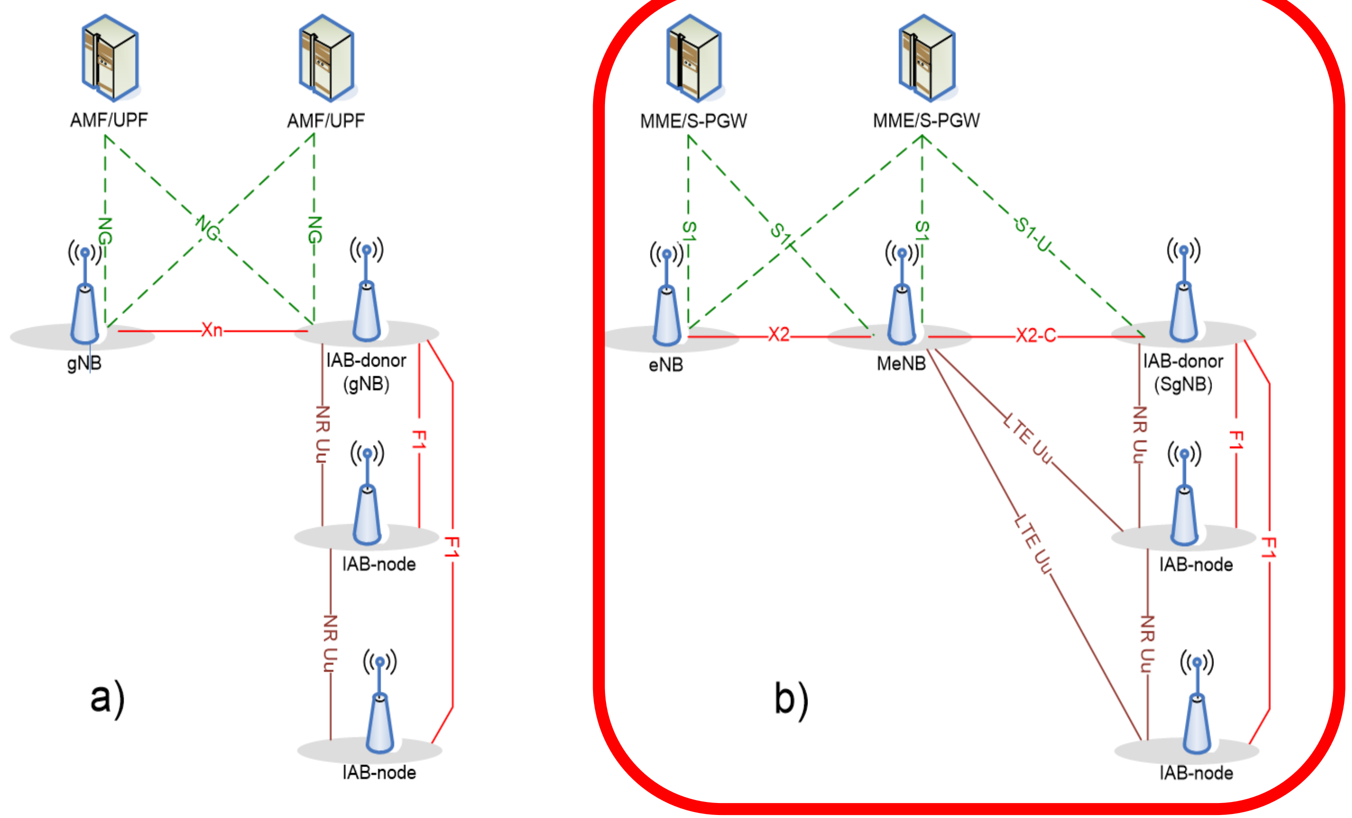


Figure : IAB architecture; a) IAB-node using SA mode with NGC; b) IAB-node using EN-DC

T-Mobile Launches Voice Over 5G NR using 5G SA Core Network

Posted on June 4, 2022 by Alan Weissberger

T-Mobile has deployed commercial **Voice over 5G (VoNR, or Voice Over (5G) New Radio)** service in limited areas of **Portland, Oregon and Salt Lake City, Utah.** The Un-carrier plans to expand VoNR to many more areas this year. Now that Standalone 5G (5G SA) is beginning to carry voice traffic with the launch of VoNR, other real 5G services, such as network slicing and security are likely to be deployed. T-Mobile customers with Samsung Galaxy S21 5G smartphones can take advantage of VoNR today in select areas.

"We don't just have the leading 5G network in the country. T-Mobile is setting the pace for providers around the globe as we push the industry forward – now starting to roll out another critical service over 5G," said Neville Ray, President of Technology at T-Mobile. "5G is already driving new levels of engagement, transforming how our customers use their smartphones and bringing unprecedented connectivity to areas that desperately need it. And it's just going to get better thanks to the incredible T-Mobile team and our partners who are tirelessly innovating and advancing the capabilities of 5G every day."

Standalone 5G removes the need for an underlying 4G LTE network and 4G core, so 5G can reach its true potential. In other words, it's "pure 5G", and T-Mobile was the first in the world to deliver it nationwide nearly two years ago.

The addition of VoNR takes T-Mobile's standalone 5G network to the next level by enabling it to carry voice calls, keeping customers seamlessly connected to 5G. In the near-term, customers connected to VoNR will notice slightly faster call set-up times, meaning less delay between the time they dial a number and the phone starts ringing. But VoNR is not just about a better calling experience. Most importantly, VoNR brings T-Mobile one step closer to truly unleashing its standalone 5G network because it enables advanced capabilities like network slicing that rely on a continuous connection to a 5G core.

PNI - NPN/SNPN (5G Private Networks) & AEF

A Non-Public Network (NPN) is a 5GS deployed for Non-Public Use

An NPN is either:

1. a Stand-alone Non-Public Network (SNPN), i.e. operated by an NPN Operator and not relying on Network Functions provided by a PLMN,

or

2. a Public Network Integrated NPN (PNI-NPN), i.e. a Non-Public Network deployed with the support of a PLMN.

NOTE: An NPN and a PLMN can share NG-RAN

Stand-alone Non-Public Networks (SNPNs)

SNPN 5GS deployments are based on the Architecture for:

- *5GC with Un-trusted Non-3GPP Access (Fig. 1-1) for access to SNPN Services via a PLMN (and vice versa)*

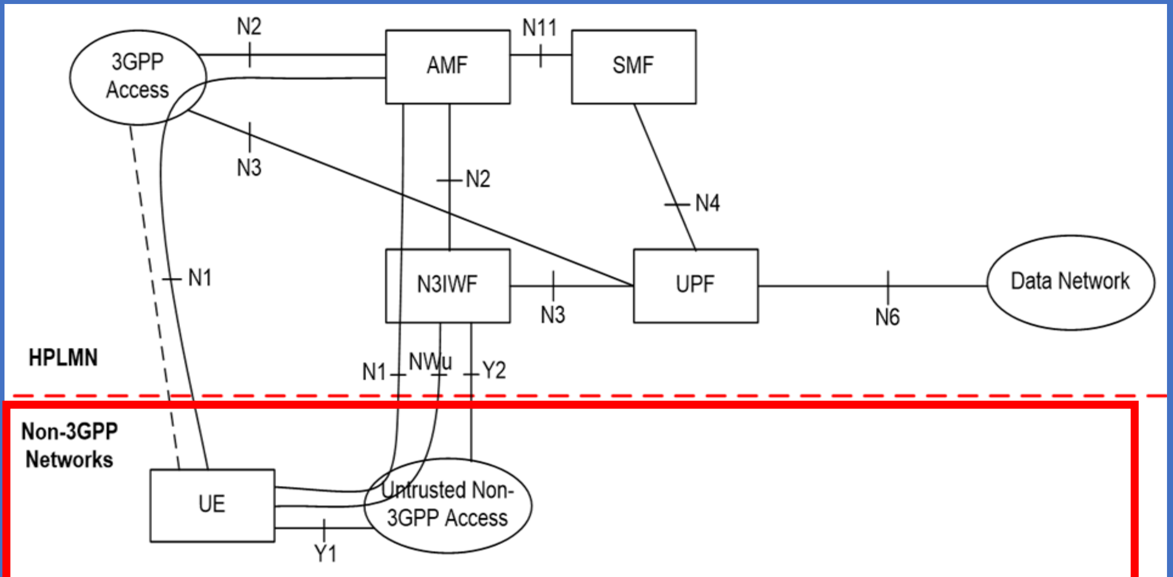


Fig. 1-1 Non-Roaming Architecture for 5G Core Network with Untrusted Non-3GPP Access

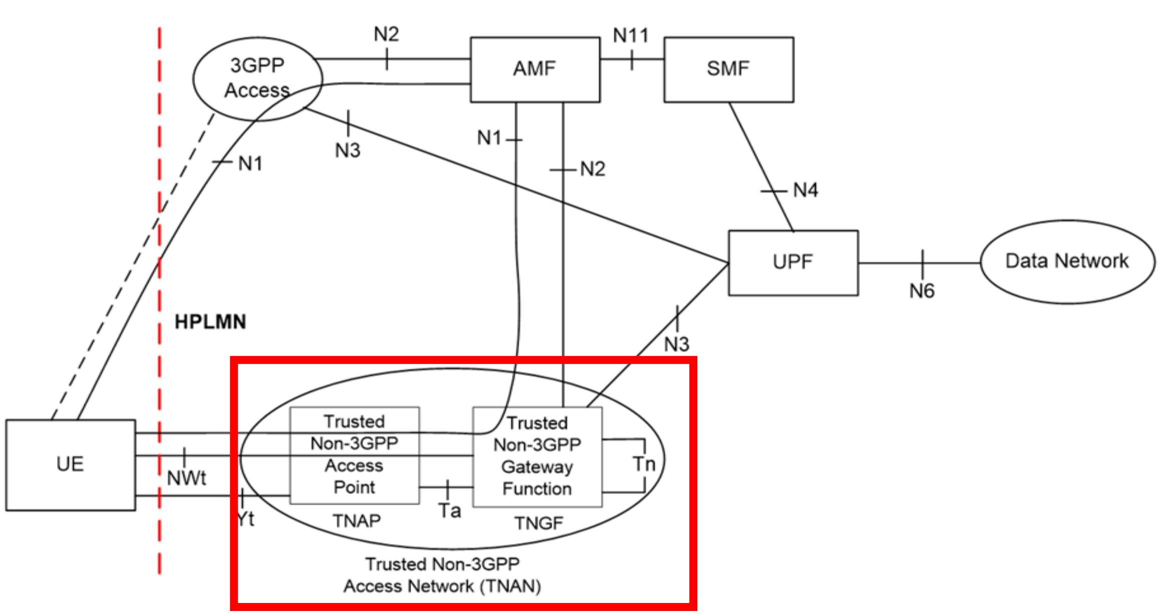


Fig. 1-2 Non-Roaming Architecture for 5G Core Network with Trusted Non-3GPP Access

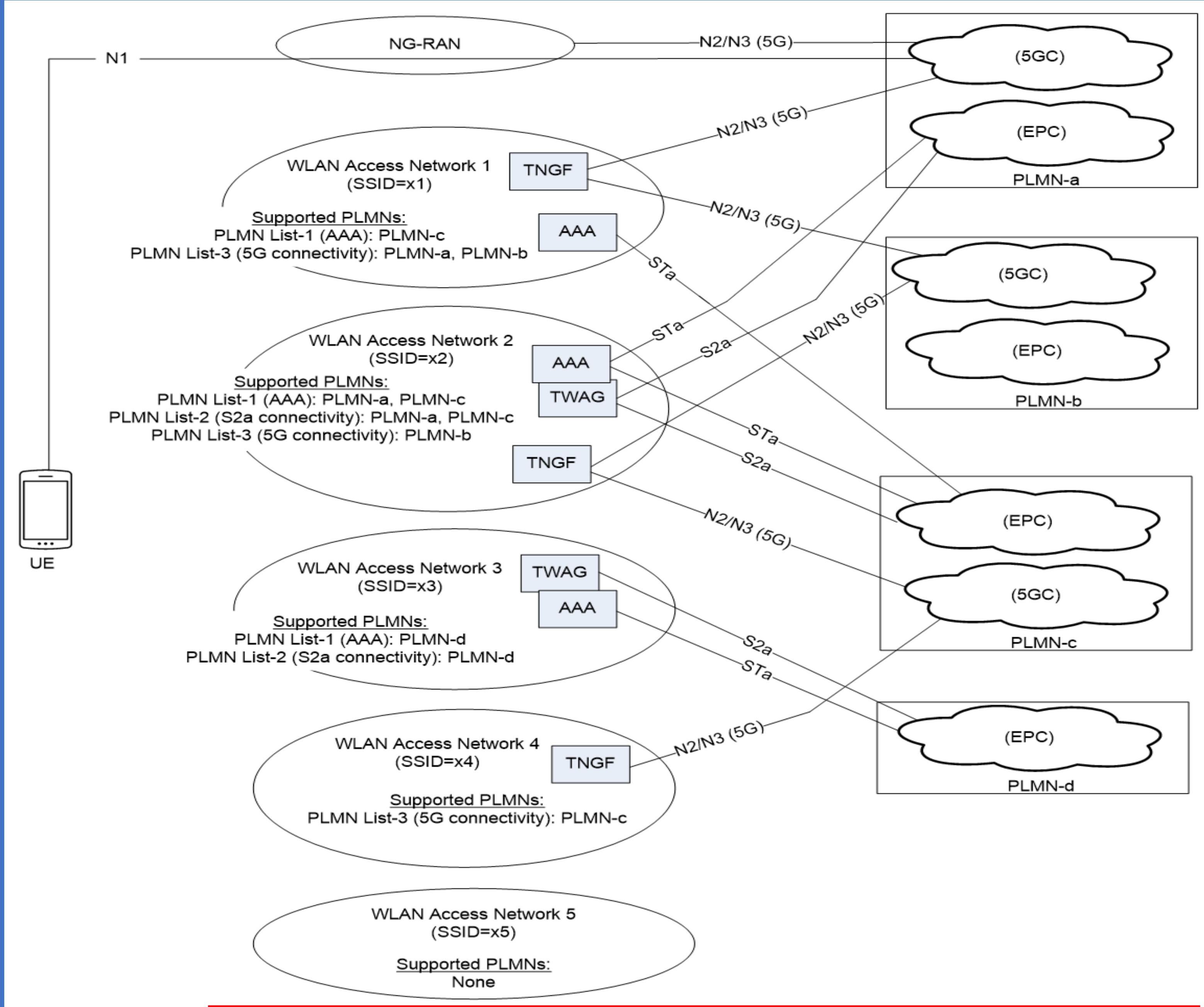


Figure Example deployment scenario for trusted Non-3GPP access network selection

NPN/SNPN Mapping Solutions to Key Issues - 3GPP Rel. 17

Nr Solutions	Key Issues: #1 Enhancements to Support SNPN along with Credentials owned by an Entity separate from the SNPN	#2: NPN support for Video, Imaging and Audio for Professional Applications (VIAPA)	#3 Support of IMS Voice and Emergency Services for SNPN	#4 UE Onboarding and Remote Provisioning	#5 Support for Equivalent SNPNs	#6 Support of Non 3GPP Access for NPN Services
1	X	X				
2	X	X				
3	X					
4	X					
5				X		
6				X		
7				X		
8	X					
9	X					
10	X					
11	X					
12	X					
13		X				
14		X				
15		X				
16		X				
17		X				
18		X				
19			X			
20			X			
21			X			
22			X			
23			X			
24			X			
25			X			
26			X			
27				X		
28				X		
29				X		
30				X		
31				X		
32				X		
33				X		
34				X		
35				X		
36				X		
37				X		
38				X		
39				X		
40				X		
41	X					
42	X					
43	X					
44	X					
45	X					
46		X				
47		X				
48		X				
49		X				
50		X				
51		X				
52		X				
53			X			
54			X			
55		X				
56			X			

1. 3GPP Definition of PNI - NPN/SNPN with Diagrams - 4

As of 3GPP Rel. 17**, the following 5GS features and functionalities are not supported for SNPNs:**

1. **Interworking with EPS** is not supported for SNPN.
2. **Emergency Services** are not supported for SNPN when the UE accesses the SNPN over NWu via a PLMN.
3. While **Roaming is not supported for SNPN**, e.g. Roaming between SNPNs, it is possible for a UE to access an SNPN with credentials from a CH
4. **Hand-over between SNPNs**, between SNPN and PLMN or PNI-NPN are **not supported.**
5. **CIoT 5GS Optimizations are not supported in SNPNs.**
6. **CAG (Closed Access Group) is not supported in SNPNs**.

- A UE with two (2) or more Network Subscriptions, where one (1) or more Network Subscriptions may be for a subscribed SNPN, can apply procedures specified for Multi-USIM UEs.

- The UE shall use a separate PEI for each network subscription when it registers to the network.

NOTE: The number of preconfigured PEIs for a UE is limited.

If the Number of Network Subscriptions for a UE is greater than the Pre-configured Number of PEIs, the Number of Network Subscriptions that can be registered with the Network simultaneously is restricted by the Number of Pre-Configured Number of PEIs.

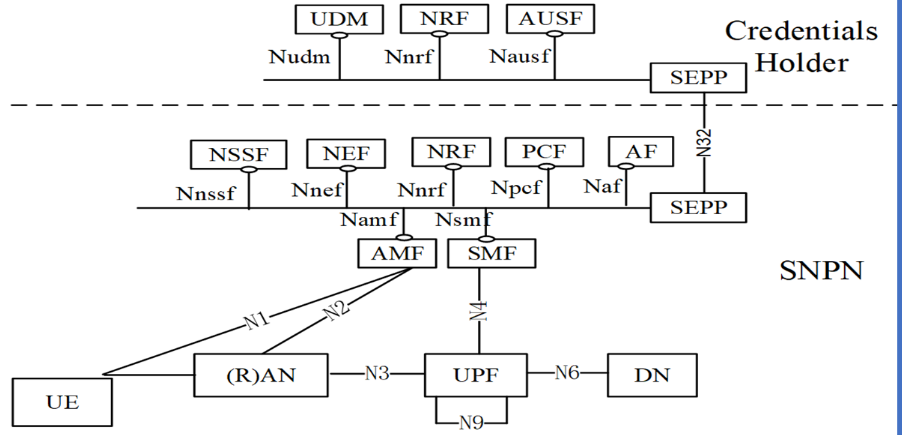


Fig. 3-1 5G System Architecture with Access to SNPN using credentials from Credentials Holder using AUSF and UDM

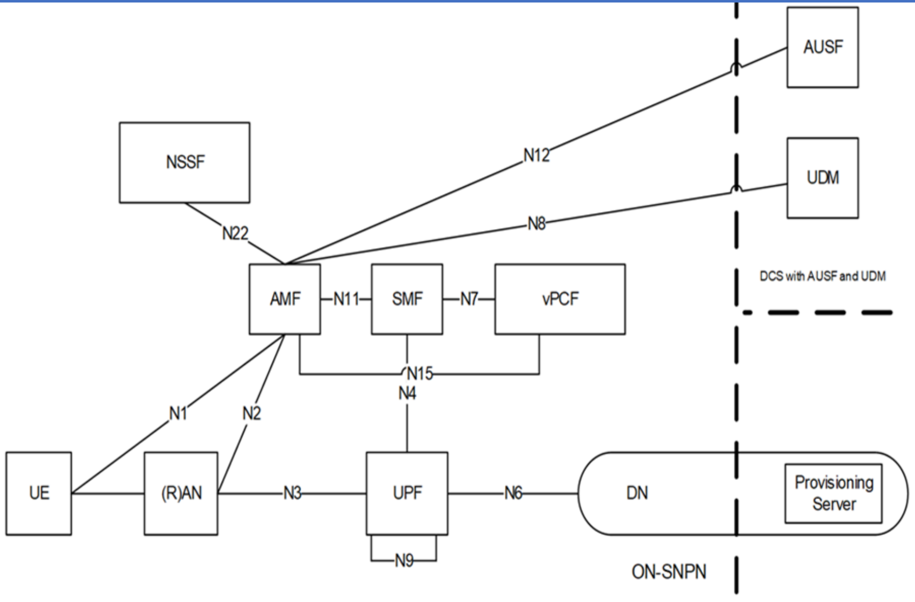


Fig.: Architecture for UE Onboarding in ON-SNPN when DCS includes AUSF and a UDM

Identifiers

The combination of a PLMN ID and Network identifier (NID) identifies an SNPN.

NOTE 1: The PLMN ID used for SNPNs is not required to be unique. PLMN IDs reserved for use by private networks can be used for non-public networks, e.g. based on mobile country code (MCC) 999 as assigned by ITU. Alternatively, a PLMN operator can use its own PLMN IDs for SNPN(s) along with NID(s), but registration in a PLMN and mobility between a PLMN and an SNPN are not supported using an SNPN subscription given that the SNPNs are not relying on network functions provided by the PLMN.

The NID shall support two assignment models:

- Self-assignment: NIDs are chosen individually by SNPNs at deployment time (and may therefore not be unique) but use a different numbering space than the coordinated assignment NIDs.
- Coordinated assignment: NIDs are assigned using one of the following two options:
  1. The NID is assigned such that it is globally unique independent of the PLMN ID used; or
  2. The NID is assigned such that the combination of the NID and the PLMN ID is globally unique.

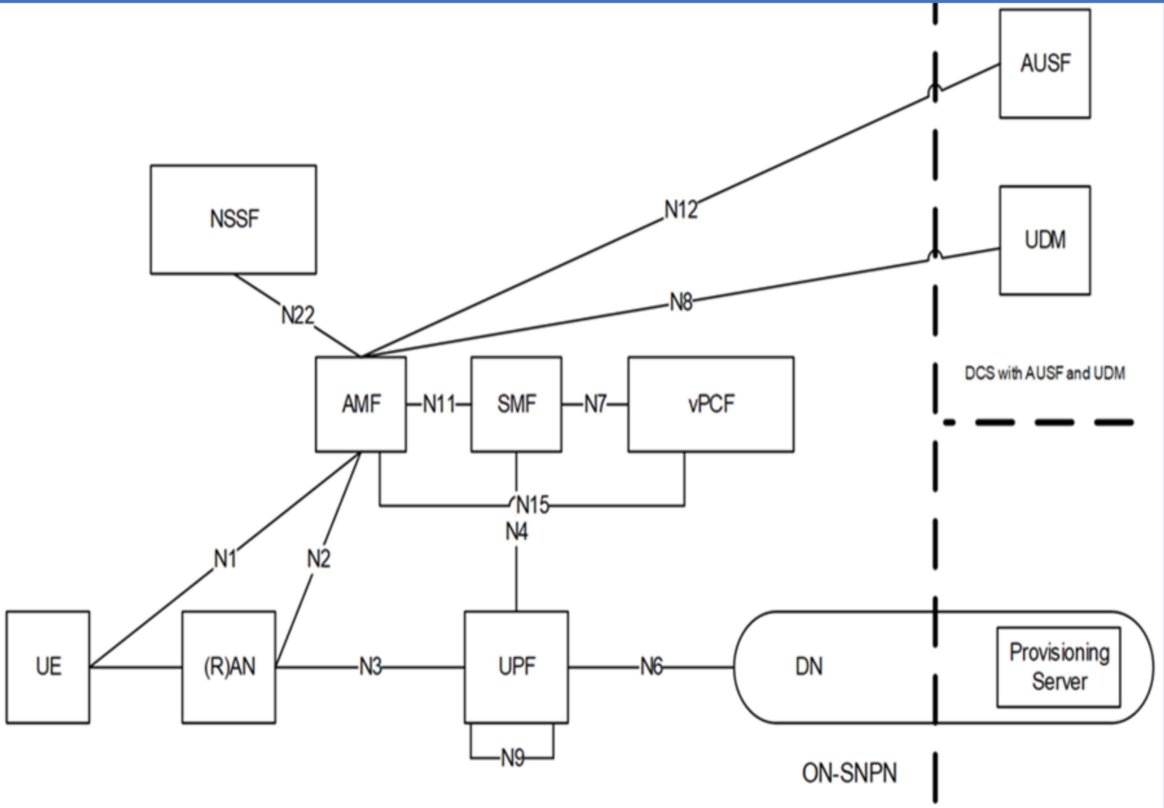


Fig.: Architecture for UE Onboarding in ON-SNPN when DCS includes AUSF and a UDM

Alternatively, **a Credentials Holder (CH)** may Authenticate and Authorize access to an SNPN.

In this Rel. 17, Direct Access to SNPN is specified for 3GPP Access only.

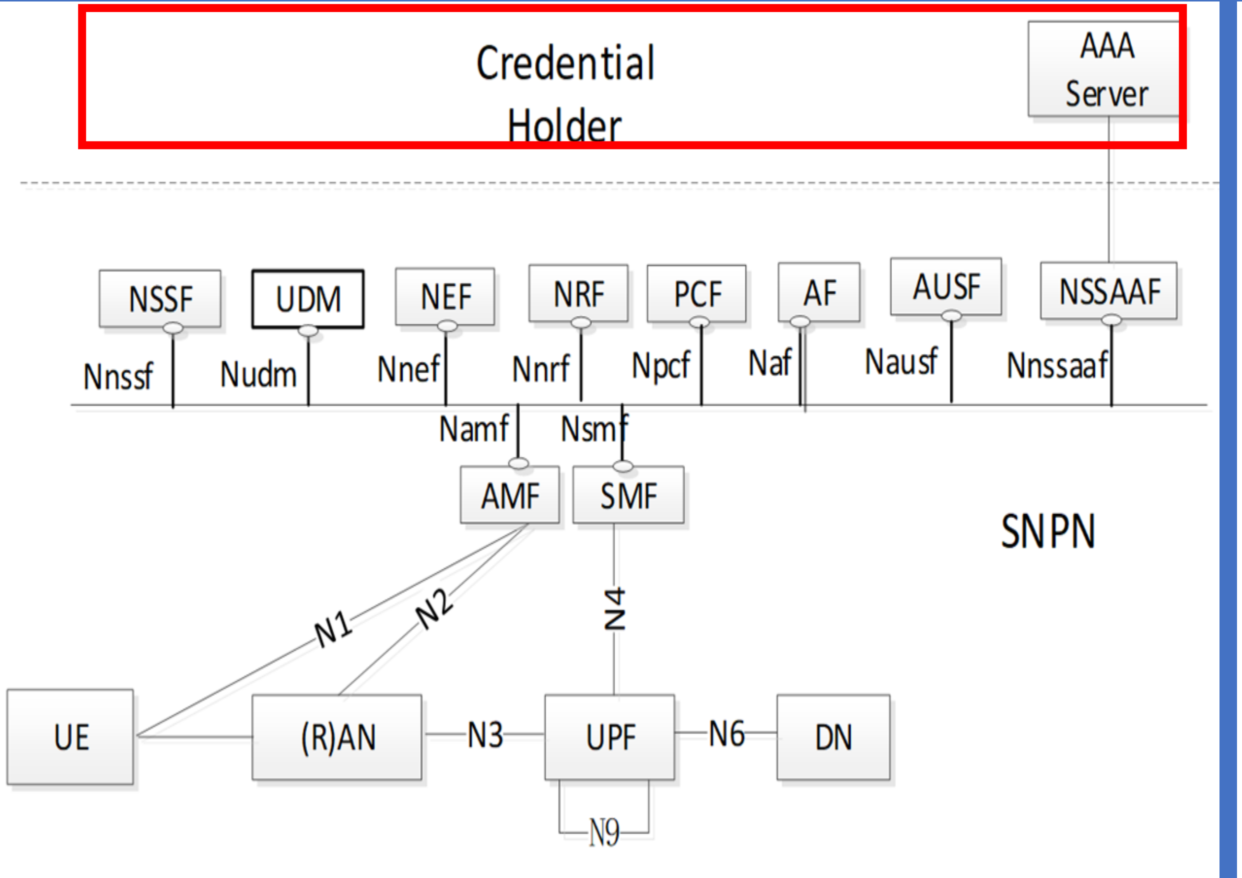


Fig. 2-1 5G System Architecture with Access to SNPN using credentials from Credentials Holder using AAA Server

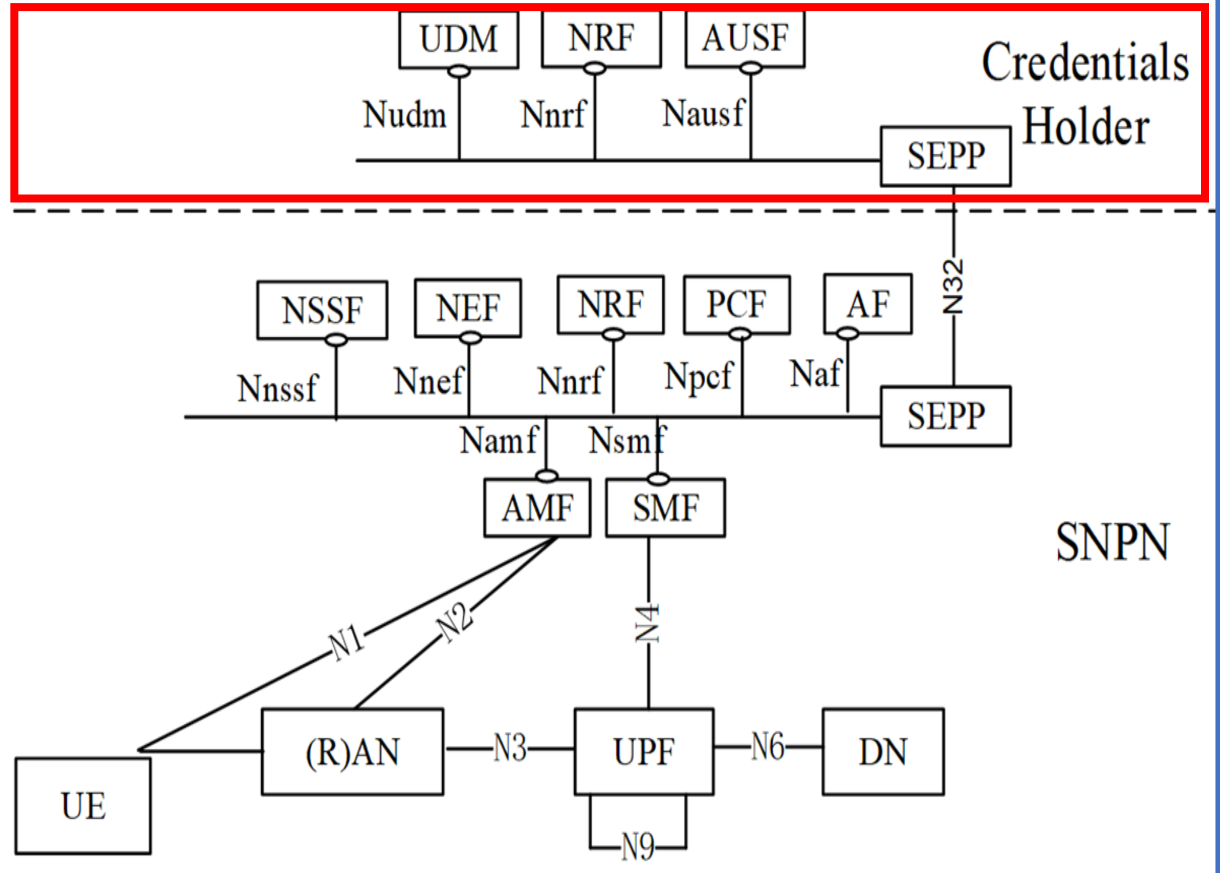


Fig. 3-1 5G System Architecture with Access to SNPN using credentials from Credentials Holder using AUSF and UDM

Ref.3GPP TS 23 501 5G System Architect., Rel., 17, Dec 2021: 337 - 338, 344

5G World in London (September 22, 2021) brought some perspective.

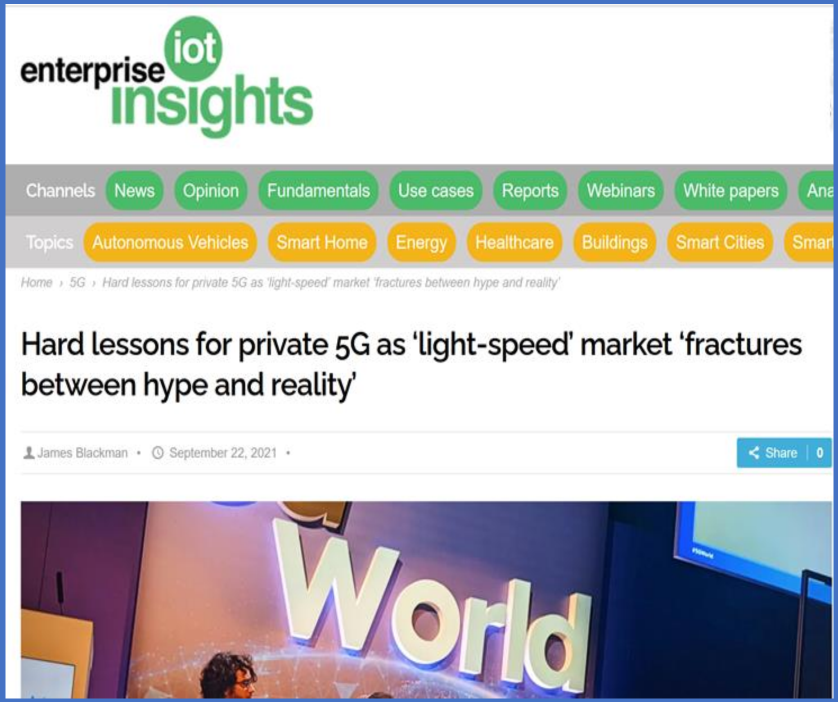
There is a Learning Curve for Enterprises, and a Learning Curve for Everyone selling Private Network Services.

So the Market is moving slower, from Tests and Proofs;

It is not even a 5G Market, yet (of course).

"The Majority is on LTE, so at moment it is an LTE Market, and LTE is currently delivering what most Use Cases want."

It looks clearer through the lens of each player in the Market, only because their views of it are all different, and all of them are feasible on their own terms.



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Hard lessons for private 5G as 'light-speed' market 'fractures between hype and reality'

James Blackman • September 22, 2021 •

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2. Market Definition and Deployments of "Private 5G" PNI - NPN/NSPN - 7

The ‘Failure’ of Private 5G – another Telco bungle, or just Industrial Inertia? (Is the Window really Closing?) ***August 31, 2021***

https://enterpriseiotinsights.com/20210831/channels/news/the-failure-of-private-5g-another-telco-bungle-or-just-industrial-inertia-is-the-window-really-closing

Most "Vertical’ Licences", so far, remain attached to PoCs.

So the early interest is from ‘Industrial Leaders’, often with vested interests in Selling solutions Over-the-Top, to kick the tyres on Private 5G.

And the Number of fully-fledged deployments are limited,

if you look at the Names of the Licensees, more than half (50%) of them are strictly speaking Non-Commercial.

Either,

1. **they are Research and / or Proofs, as you rightly mention, or [else]**
2. **they are System-Integrator (SI) Deployments – [all of which] want to Test and Showcase 5G Solutions they are looking to provide to clients.**

The question then becomes what level of PNI-NPN will emerge as the most successful.”

NPN/SNPN

Approved 5G Advanced Logo

1. Key Issue #1: Enabling support for idle and Connected mode Mobility between SNPNs without New Network selection

2. Key Issue #2: Support of Non-3GPP Access for SNPN

3. Key Issue #3: Enabling NPN as hosting network for providing Access to Localized Services

4. Key Issue #4: Enabling UE to Discover, Select and Access NPNs as Hosting Network and receive Localized Services

5. Key Issue #5: Enabling Access to Localized Services via a Specific Hosting Network

6. Key Issue #6: Support for returning to Home Network

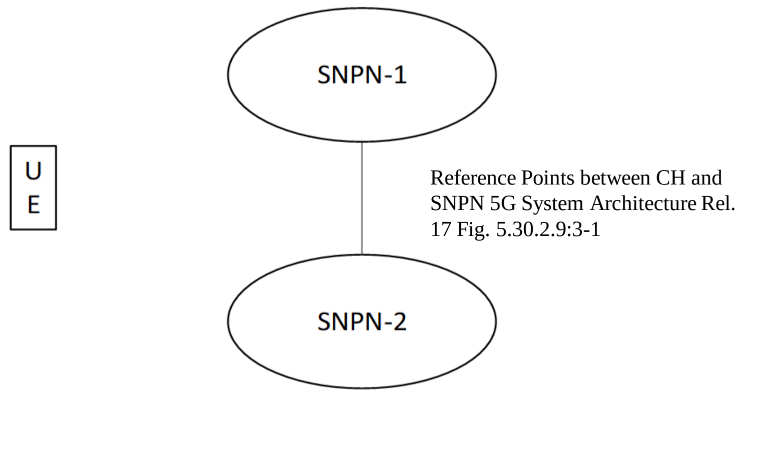


Figure UE accesses multiple SNPNs using CH

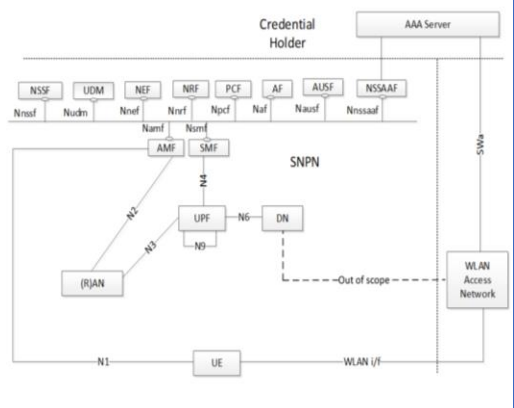


Figure : Access to SNPN with NG-RAN and to WLAN Access Network using the same credentials

Mapping Solutions to Key Issues

Table Mapping Solutions to Key Issues

	Key Issues					
Solutions	1	2	3	4	5	6
1	X					
2		X				
3		X				
4		X				
5		X				
6		X				
7			X	X	X	X
8						X
9						X
10				X		X
11					X	
12				X		
13				X	X	
14				X		
15				X	X	
16		X				
17						X
18					X	

Support for Local Area Data Network (LADN)

A LADN Service Area (SA) is a set of Tracking Areas (TAs).

LADN is a service provided by the serving PLMN.

It includes:

- LADN Service applies only to 3GPP Accesses and does not apply in Home Routed case.
- The usage of LADN DNN requires an explicit subscription to this DNN or subscription to a wildcard DNN.
- Whether a DNN corresponds to a LADN Service is an attribute of a DNN and is per PLMN.

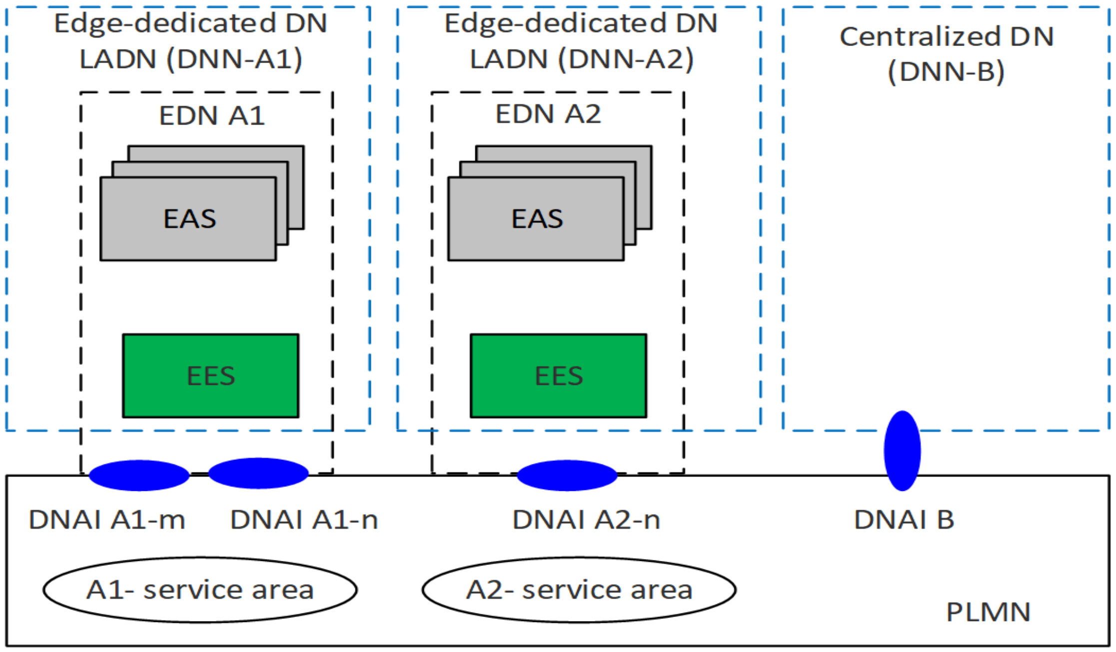
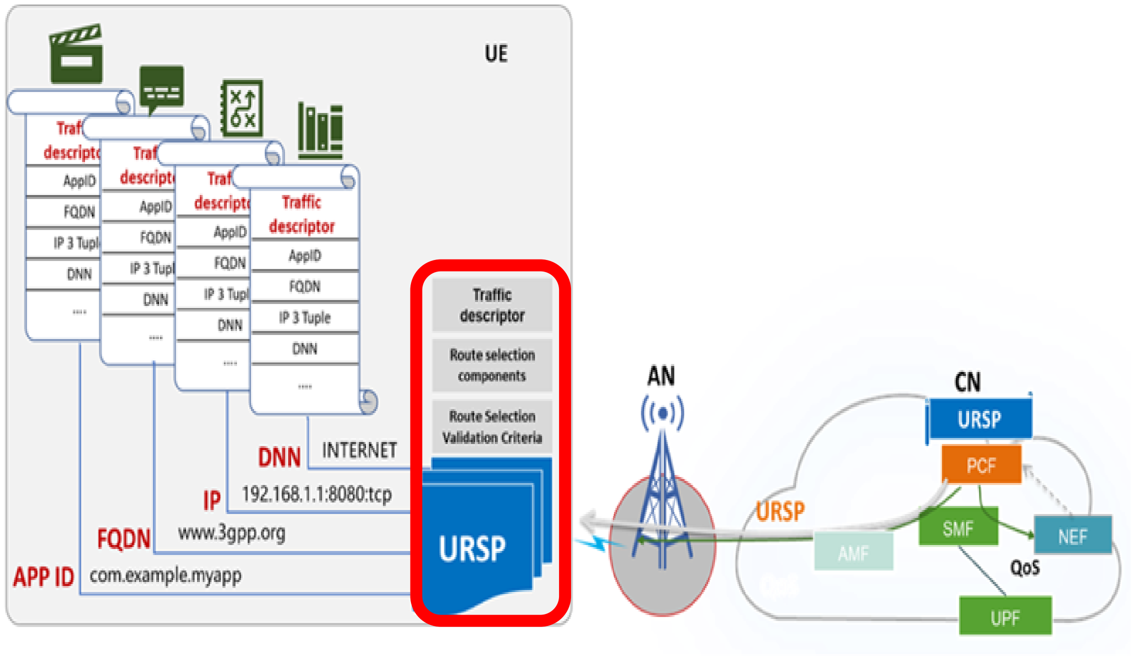


Figure : Option 3: Use of LADN(s)



URSP - UE Route Selection Policy URSP

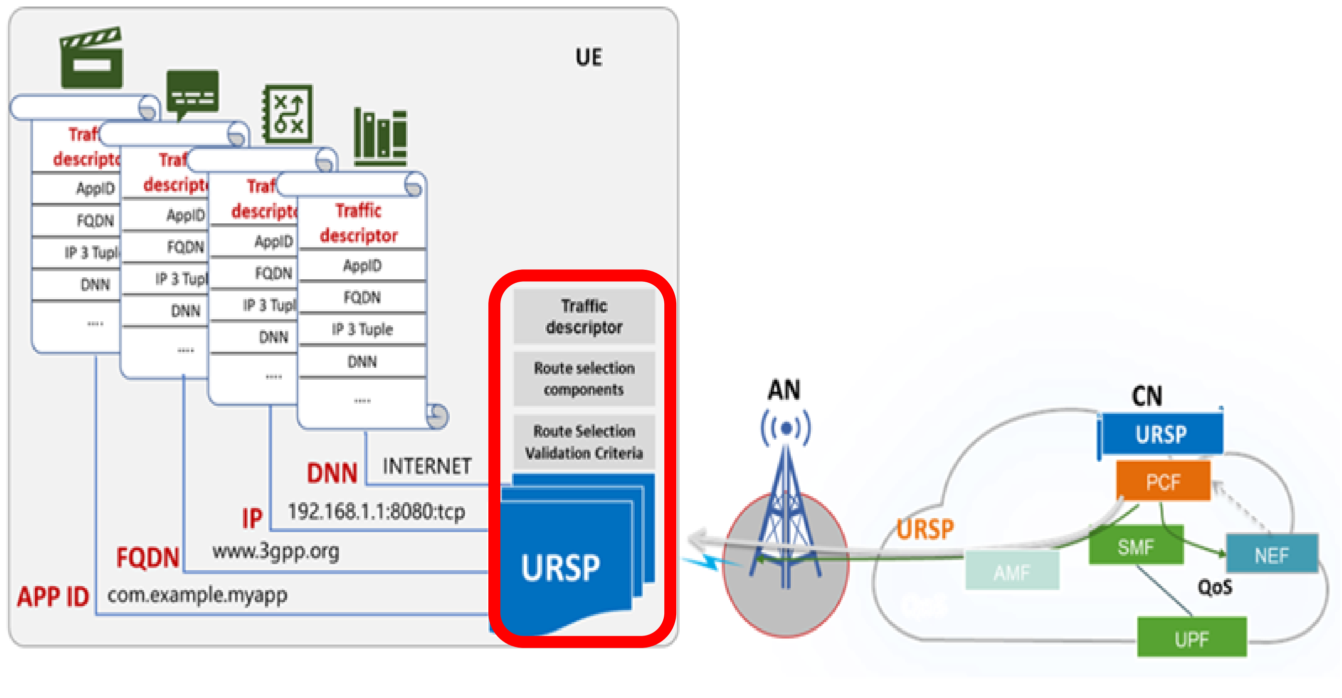
The URSP is defined and is a set of one or more URSP rules, where a URSP rule is composed of:

a) A precedence value of the URSP rule identifying the precedence of the URSP rule among all the existing URSP rules;

b) A traffic descriptor, including either:
 1) match-all traffic descriptor; or
 2) at least one of the following components:
  A) one or more application identifiers;
  B) one or more IP 3 tuples: Destination/ 1. IP Address 2. Port nr, & 3. the Protocol
  C) one or more non-IP descriptors, i.e. destination information of non-IP traffic;
  D) one or more DNNs;
  E) one or more connection capabilities; and
  F) one or more domain descriptors, i.e. destination FQDN(s) or a regular expression as a Domain Name matching criteria; and

c) one or more route selection descriptors each consisting of a precedence value of the route selection descriptor and either
 1) one PDU session type and, optionally, one or more of the followings:
  A) SSC mode;
  B) 1 or more S-NSSAIs;
  C) 1 or more DNNs;
  D) Void;
  E) preferred Access Type;
  F) Multi-Access Preference;
  G) a Time Window; and
  H) Location Criteria;

 2) non-seamless non-3GPP offload indication; or
 3) 5G ProSe Layer-3 UE-to-network relay offload indication



PALS Consolidated Potential Requirements (CPR) -

NOTE 1: **Both the Home and the Hosting Network can be a PLMN or NPN.**

NOTE 2: Only Subscribers of a Public Network can roam into a PLMN.

Table - Configuration of Localized Services in Hosting Network Consolidated Requirements

CPR #	Consolidated Potential Requirement	Original PR #	Comment
CPR 6.1-001	The 5G network shall support suitable mechanisms to allow automatically establishing localized service agreements for a specific occasion (time and location) and building temporary relationship among hosting network operator and other service operators including network operators or 3rd party service providers.	PR.5.3.6-1	
CPR 6.1-002	The 5G system shall support means for the service operator to request the hosting network via standard mechanisms to provide access to 3rd party services at a specific period of time and location. This period of time shall be flexible, so that a change in service provision can be decided at any time (e.g., to cancel or prolong local services in the locality of service delivery) based on localized services agreements.	PR.5.5.6-1	
CPR 6.1-003	Based on localized services agreements, the 5G system shall provide suitable means to allow the service operator to request and provision various localized service requirements, including QoS, expected/maximum number of users, event information for discovery, network slicing, required IP connectivity etc, and routing policies for the application of the localized services via the hosting network.	PR.5.5.6-2 and PR.5.4.6-1	
CPR 6.1-004	The 5G system shall support means for a hosting network to create policies and configure resources for the requested time and location for the 3rd party services based on the received request.	PR.5.5.6-3	
CPR 6.1-005	The 5G system shall support means for a hosting network to notify the service operator of the accepted service parameters and routing policies.	PR.5.5.6-4	
CPR 6.1-006	Subject to regulatory requirements and localized service agreements, the 5G network shall allow a home network operator to automatically negotiate policies with the hosting network for allowing the home network's subscribers to connect at a specific occasion, e.g., time and location, for their home network services.	PR.5.3.6-2	
CPR 6.1-007	Subject to the automatic localized services agreements between the hosting network operator and home network operator, for UE with only home network subscription and with authorization to access hosting networks the 5G system shall support: - access to the hosting network and use home network services or selected localized services via the hosting network. - seamless service continuity for home network services or selected localized services when moving between two hosting networks or a host network and the home network.	PR.5.3.6-5	
CPR 6.1-008	The 5G System shall support a mechanism to enable configuration of a network that provides access to localized services such that the services can be limited in terms of their spatial extent (in terms of a particular topology, for example a single cell), as specified by a 3rd party.	PR.5.10.6-1	
CPR 6.1-009	The 5G System shall support a mechanism to enable configuration of a network that provides access to localized services such that the services can be limited in terms of the resources or capacity available, to correspond to requirements that apply only to the locality of service delivery, as specified by a 3rd party.	PR.5.10.6-2	
CPR 6.1-010	The 5G system shall support means for a hosting network to provide a 3rd party service provider with information for automatic discovery of the hosting network by the UEs to allow access to specific 3rd party services.	PR.5.6.6-1	
CPR 6.1-011	The 5G system shall support secure mechanisms to allow a home network to coordinate with a hosting network for a subscriber to temporarily access the hosting network (e.g., based on temporary credentials) at a given time (start time and duration) and location.	PR.5.8.6-1	

PALS Consolidated Potential Requirements (CPR) -

NOTE 1: **Both the Home and the Hosting Network can be a PLMN or NPN.**

NOTE 2: Only Subscribers of a Public Network can roam into a PLMN.

User Manual Selection of Localized Services via Hosting Network

Table - User Manual Selection of Localized Services via Hosting Network Consolidated Requirements

CPR #	Consolidated Potential Requirement	Original PR #	Comment
CPR 6.2-001	The hosting network shall allow a UE to manually select temporary localized services which are provided via local breakout at the hosting network. NOTE : localized services are provided via local breakout at the hosting network based on interworking scenarios for hosting network owned/collaborative services as indicated in Annex A.	PR.5.4.6-2	

UE Configuration, Provisioning, Authentication & Authorization

Table - UE Configuration, Provisioning, Authentication and Authorization Consolidated Requirements

CPR #	Consolidated Potential Requirement	Original PR #	Comment
CPR 6.3-001	Subject to localized services agreements, the 5G network shall enable a home network operator to authorize a UE for using its home network services via a hosting network for a certain period of time and/or location.	PR.5.3.6-3	
CPR 6.3-002	The 5G network shall allow a trusted 3rd party to provide UEs with localized service policy (e.g., QoS, network slice in the hosting or home network, service restriction such as time and location) via the hosting network or the UE's home network.	PR.5.4.6-1A	
CPR 6.3-003	The 5G system shall enable a UE to use credentials provided by the hosting network with or without coordination with the home network of the UE, to make use of localized services via the hosting network with a certain time (including starting time and the duration) and location validity.	PR.5.4.6-7	
CPR 6.3-004	The 5G network shall be able to allow the home network to steer its UE(s) to a hosting network with the consideration of the location, times, coverage of the hosting network and services offered by the home network and hosting network.	PR.5.11.6-1	
CPR 6.3-005	The 5G system shall provide support to enable secure means to authenticate and authorize a user of a UE accessing a hosting network, including cases in which a UE has no subscription to the hosting network and still needs to get authorized to use localized services via the hosting network. NOTE : It can be assumed that a network provider deploying a hosting network has access to respective identification information about the user, e.g., through a separate registration process outside the scope of 3GPP.	PR.5.15.6-2	
CPR 6.3-006	The 5G system shall be able to authenticate and authorize the UE of a user authenticated to a hosting network to access the hosting network and its localized services on request of a service provider.	PR.5.15.6-3 and PR.5.2.6-2	

PALS Consolidated Potential Requirements (CPR) -

NOTE 1: **Both the Home and the Hosting Network can be a PLMN or NPN.**

NOTE 2: Only Subscribers of a Public Network can roam into a PLMN.

Hosting Network Localized Services and Home Operator Services

Table - Hosting Network Localized Services and Home Operator Services Consolidated Requirements

CPR #	Consolidated Potential Requirement	Original PR #	Comment
CPR 6.5-001	The 5G network shall enable the home network operator to indicate to the UE what services are preferred to be used from the home network when the UE connects to a hosting network and the requested services are available from both the hosting and the home network.	PR.5.3.6-4	
CPR 6.5-002	Based on localized service agreements, the hosting network shall be able to provide required connectivity and QoS for a UE simultaneously connected to the hosting network for localized services and its home network for home network services.	PR.5.4.6-3	
CPR 6.5-003	A UE shall be able to connect to its home network via the hosting network, if supported by the hosting network and the home network based on localized service agreements.	PR.5.4.6-4	

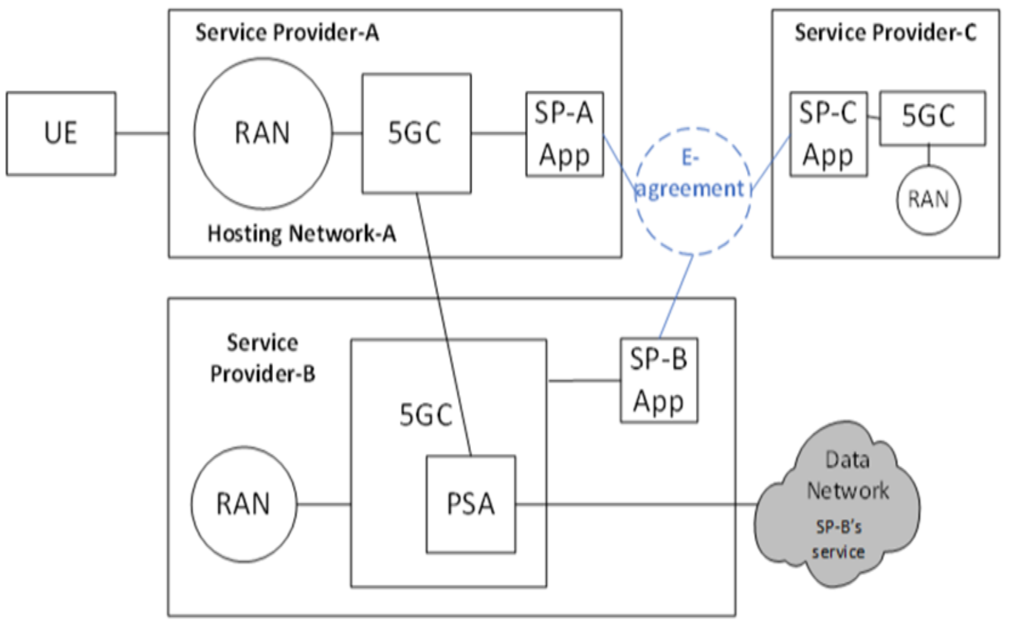
Returning to Home Network

Table - Returning to Home Network Consolidated Requirements

CPR #	Consolidated Potential Requirement	Original PR #	Comment
CPR 6.6-001	The 5G system shall provide mechanisms to mitigate user plane and control plane overload caused by a high number of UEs returning from a temporary local access of a hosting network to their home network in a very short period of time.	PR.5.14.6-1	
CPR 6.6-002	The 5G system shall provide mechanisms to minimize the impact on the UEs communication e.g., to prevent user plane and control plane outages when returning to a home network together with other high number of UEs in a very short period of time, after terminating their temporary local access to a hosting network.	PR.5.14.6-2	

PALS The Application Layer Approaches require 5G Network to expose Network Capabilities for Localized Services

As shown in the Figure, the e-Agreement is established among Service Operators, e.g. SP-A, SP-B, and SP-C have no SLAs in place for the Service provided by SP-A's Hosting Network - A.



Network Operators (MNOs) Relationship using Application Layer Approach

The SP-A Operator creates an e-Agreement which provides the Localized Service Configuration.

The SP-B and SP-C Operators can subscribe this Localized Service with required Service Policies for their UEs.

The SP-B and SP-C can then configure their UEs for Localized Service.

Based on the e-Agreement, the Hosting Network can be configured with Localized Service at a specific time & location for its subscribers (other Network Operator), e.g. Localized Service Policies of Time, Location, Network-A Access Parameters, including Spectrum, Access Technologies (3GPP or non-3GPP), Network Slice, Charging Policies, and Subscriber's Network Policies for Authentication, and Routing.

5G NFs SFC - Service Function Chaining

Solutions shall build on the 5G System Architectural Principles including Flexibility and Modularity for newly introduced functionalities (**3GPP defined FMSS**).

- Service path (i.e. for Traffic handled by the Service Functions (SFs)) is traversed over N6 after PSA UPF(s) in 5G network.

Currently, the SMF may be configured with the Traffic Steering policy related to the mechanism enabling traffic steering to the N6-LAN, DN and/or DNAIs associated with N6 traffic routing requirements provided by the AF.

- UPF with SFC capabilities need to support flexible SFC configuration for a PDU session that requires different SFC processing for different Applications.

For allowing an AF, e.g. a 3rd Party AF, to request predefined SFC for Traffic Flow(s), etc. (when the AF belongs to a 3rd Party, this is based on Service Level Agreement (SLA) with the 3rd Party).

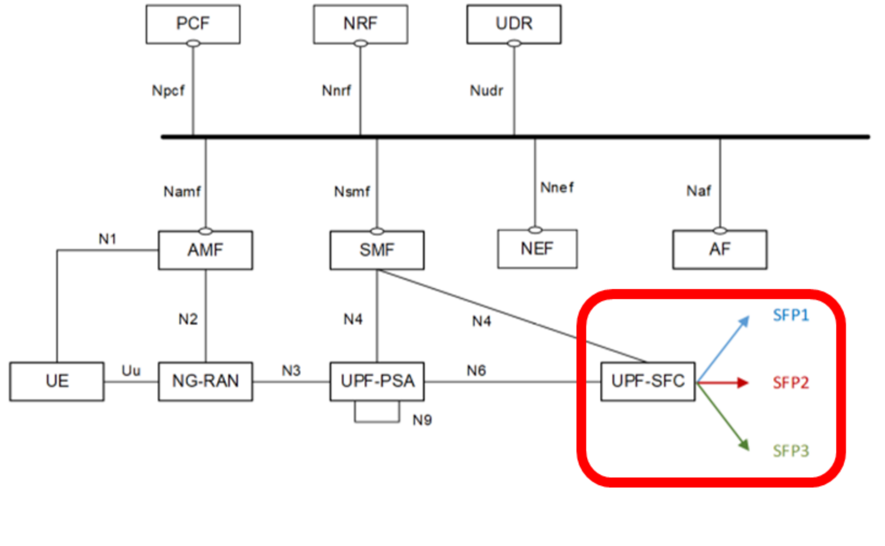


Figure : 5G system architecture for SFC support

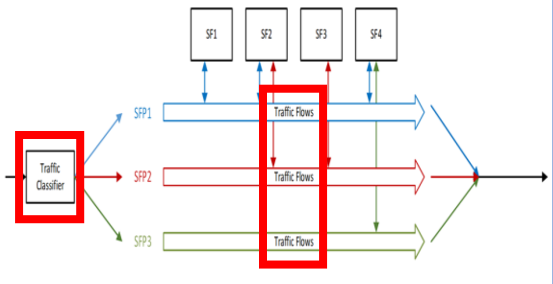
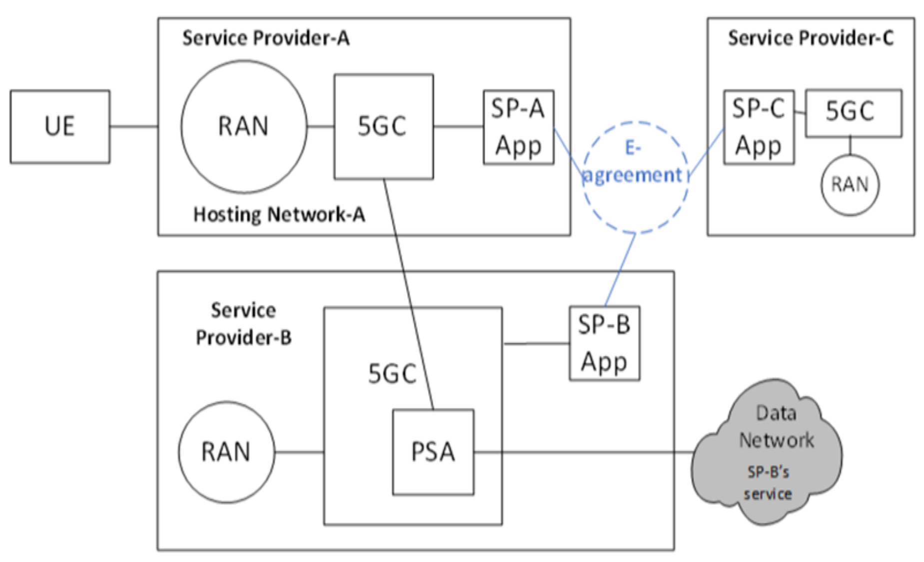


Figure : Illustration of the service function chaining concepts



Network Operators (MNOs) Relationship using Application Layer Approach

PALS Interworking between Networks Operators and Application Providers for Localized Services

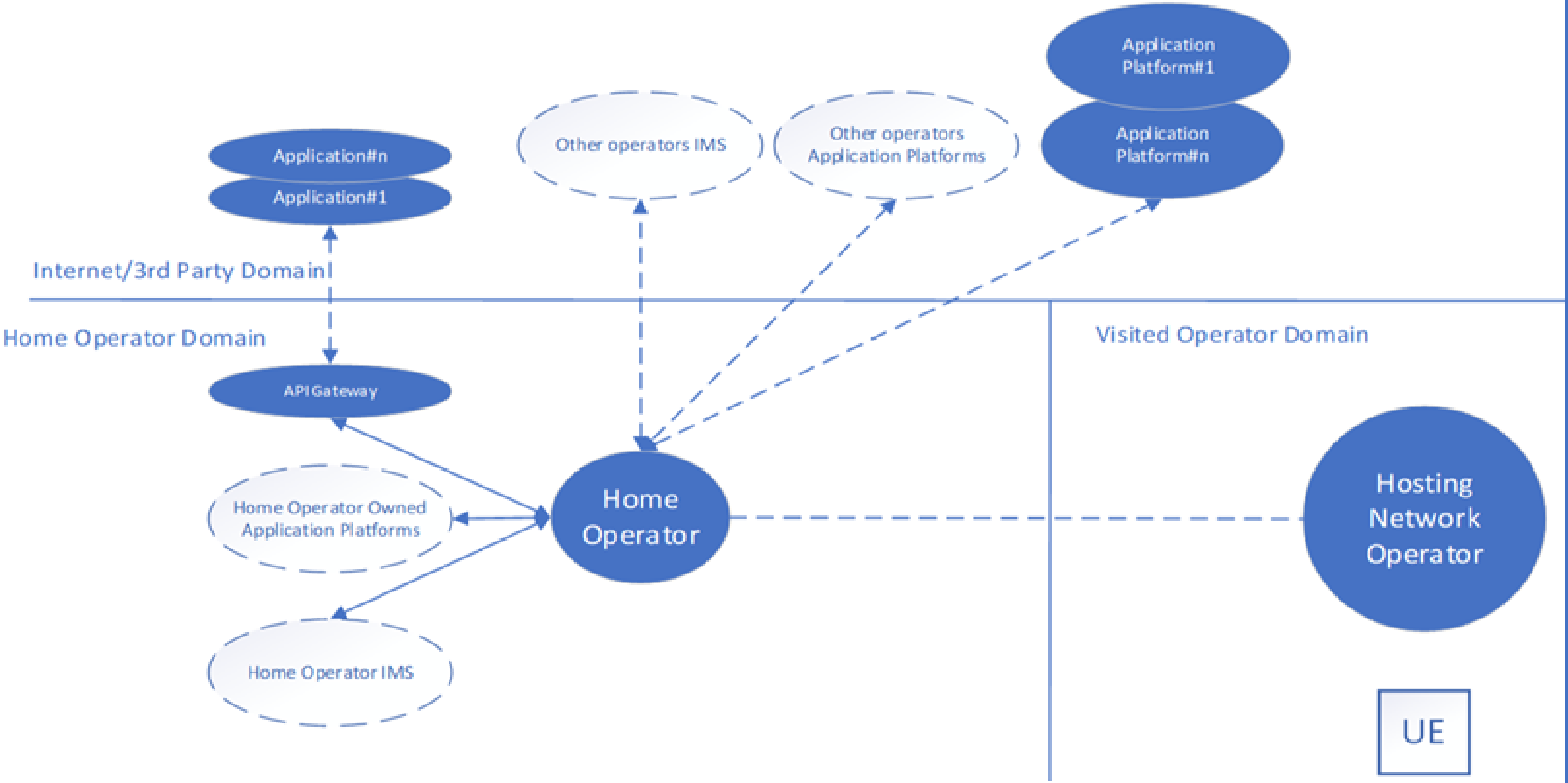


Fig.: Home Operator owned/collaborative Roaming Scenario - Home Routed

PALS Interworking between Networks Operators and Application Providers for Localized Services

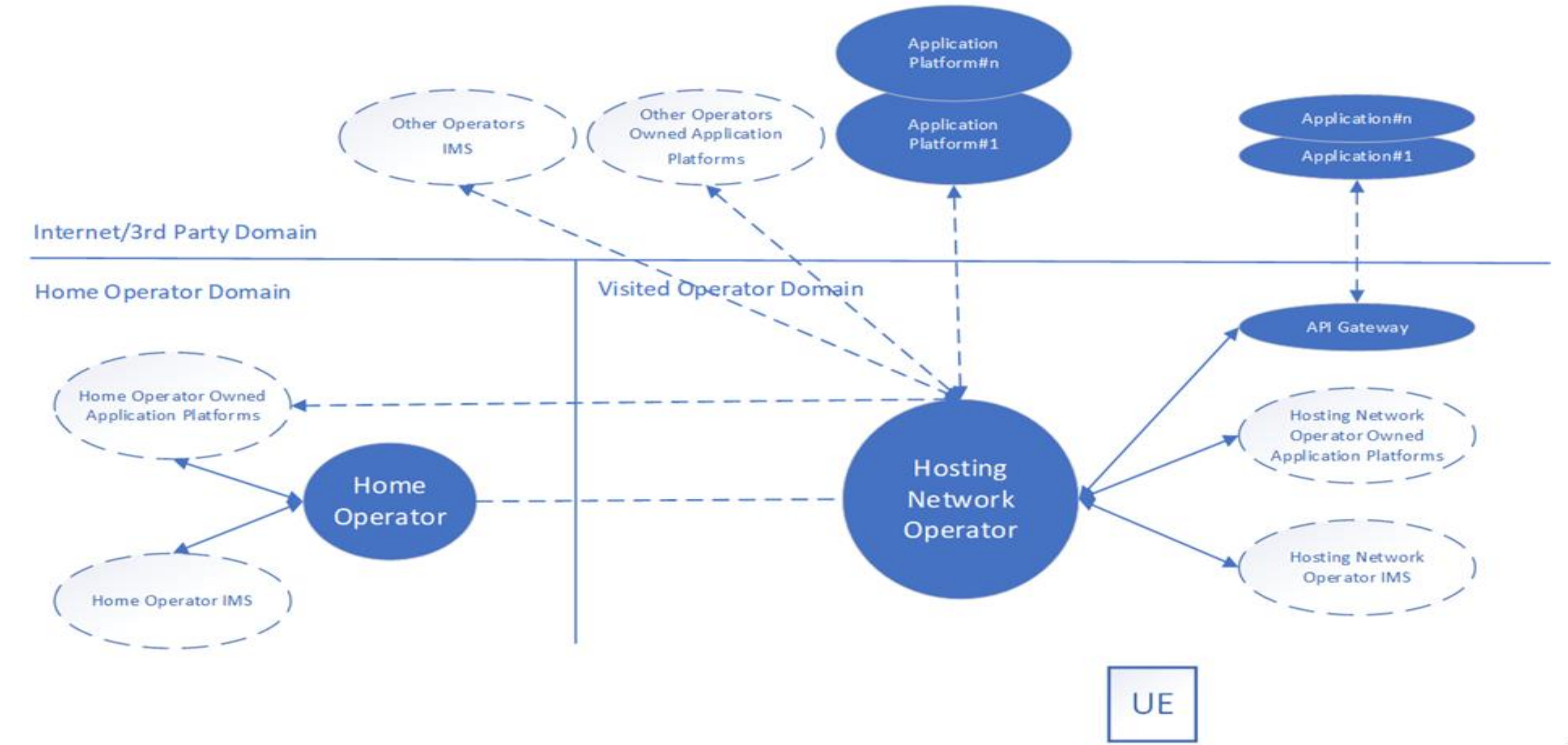


Fig.: Hosting Network Operator owned/collaborative Roaming Scenario - Local Breakout

AEF Capabilities

Potential enhancements in CAPIF and **Application Enablement Frameworks (e.g. SEAL, EDGEAPP, Vertical Enabler Layers**) to support the Subscriber-aware Northbound API Access (SNA), .

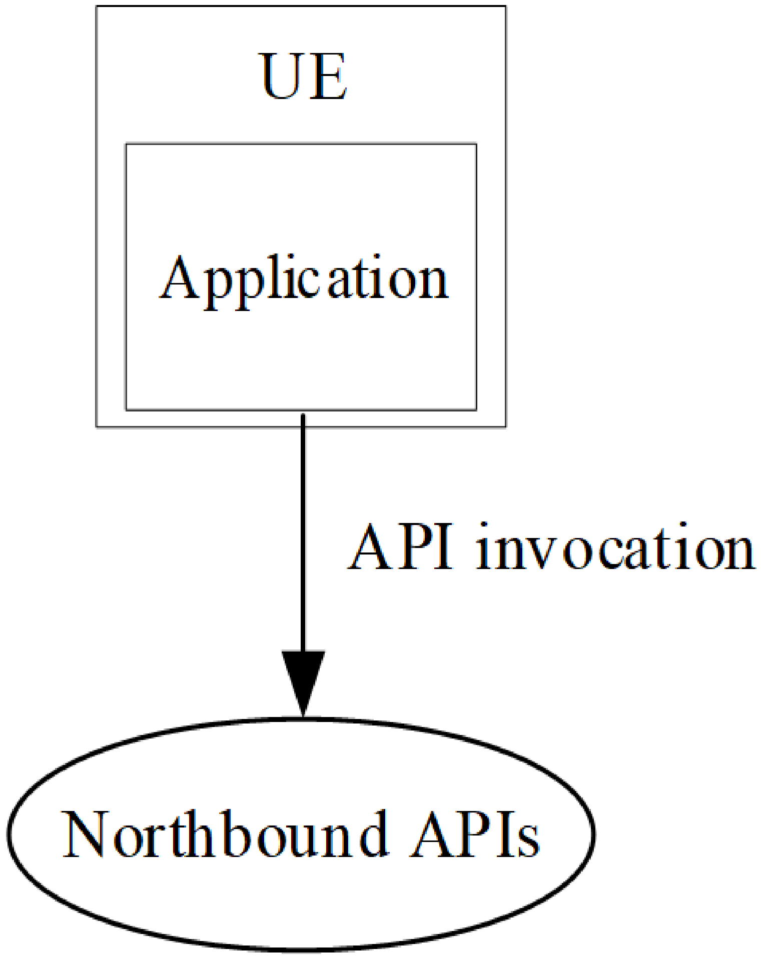


Figure: UE-originated API invocation

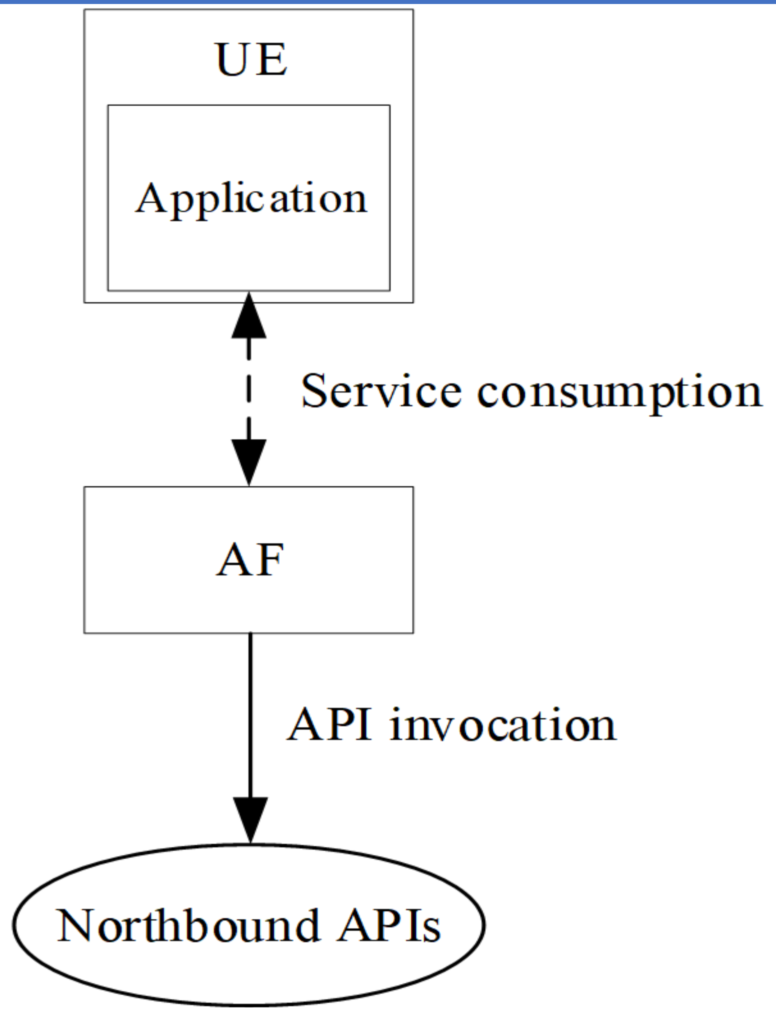


Figure .: AF-originated API invocation

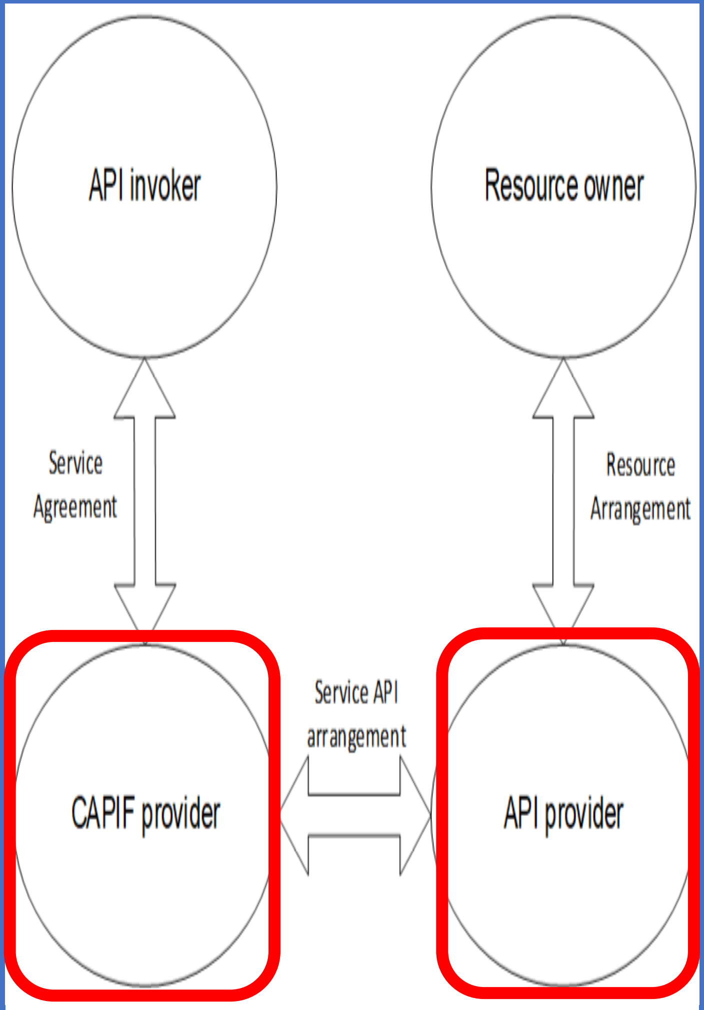


Fig.: Business Relationship in SNA

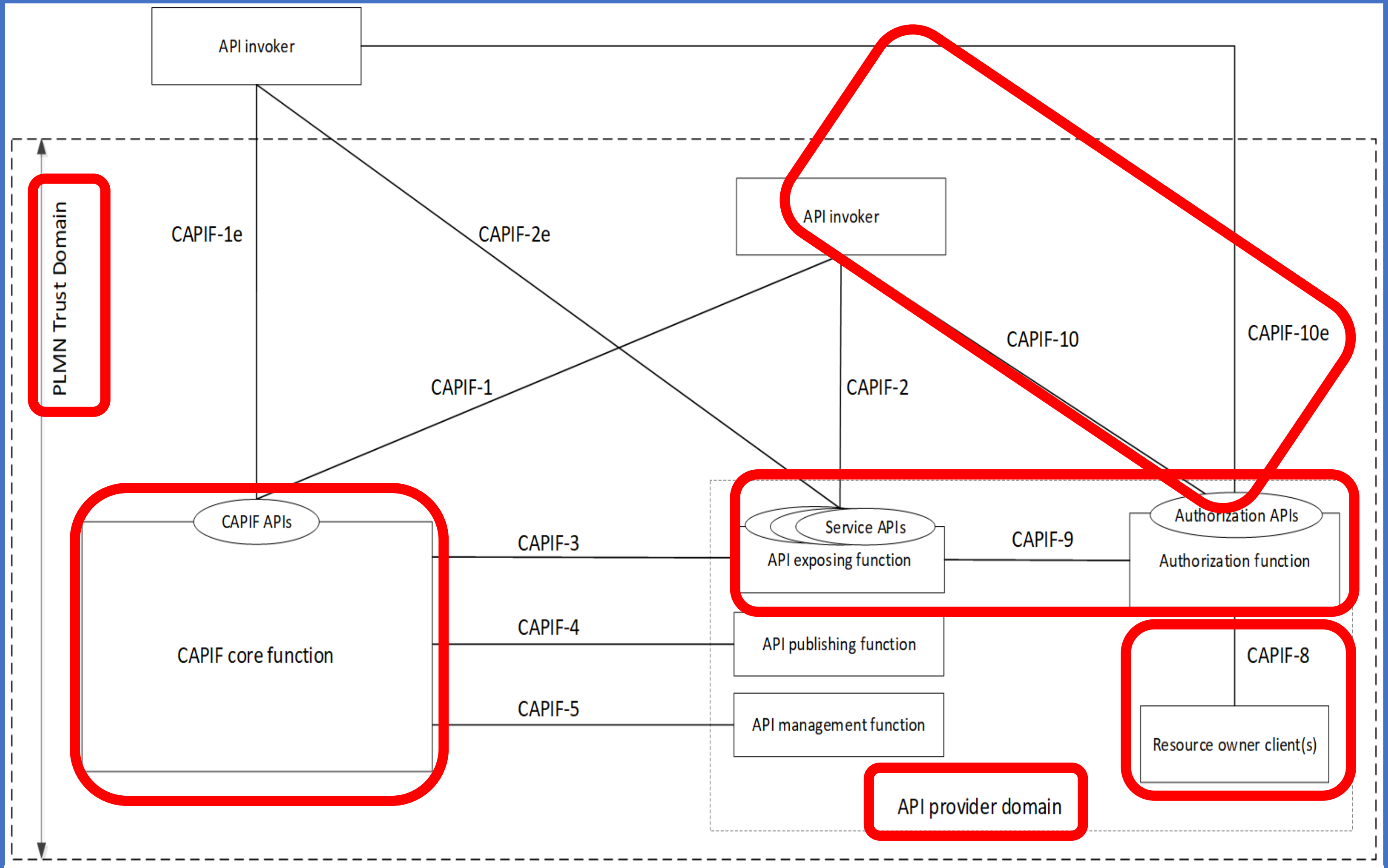


Fig.: Functional Model for the CAPIF with SNA enhancements

5G UE Service Access Identities and Service Access Categories Configurations

Table 1: 5G User Equipment (UE) Service Access Identities Configuration

Access Identity number	UE configuration
0	UE is not configured with any parameters from this table
1 (NOTE 1)	UE is configured for Multimedia Priority Service (MPS).
2 (NOTE 2)	UE is configured for Mission Critical Service (MCS).
3	UE for which Disaster Condition applies (note 4)
4-10	Reserved for future use
11 (NOTE 3)	Access Class 11 is configured in the UE.
12 (NOTE 3)	Access Class 12 is configured in the UE.
13 (NOTE 3)	Access Class 13 is configured in the UE.
14 (NOTE 3)	Access Class 14 is configured in the UE.
15 (NOTE 3)	Access Class 15 is configured in the UE.

NOTE 1: Access Identity 1 is used by UEs configured for MPS, in the PLMNs where the configuration is valid. The PLMNs where the configuration is valid are HPLMN, PLMNs equivalent to HPLMN, and visited PLMNs of the home country.
Access Identity 1 is also valid when the UE is explicitly authorized by the network based on specific configured PLMNs inside and outside the home country.

NOTE 2: Access Identity 2 is used by UEs configured for MCS, in the PLMNs where the configuration is valid. The PLMNs where the configuration is valid are HPLMN or PLMNs equivalent to HPLMN and visited PLMNs of the home country. Access Identity 2 is also valid when the UE is explicitly authorized by the network based on specific configured PLMNs inside and outside the home country.

NOTE 3: Access Identities 11 and 15 are valid in Home PLMN only if the EHPLMN list is not present or in any EHPLMN. Access Identities 12, 13 and 14 are valid in Home PLMN and visited PLMNs of home country only. For this purpose, the home country is defined as the country of the MCC part of the IMSI.

NOTE 4: The configuration is valid for PLMNs that indicate to potential Disaster Inbound Roamers that the UEs can access the PLMN. See clause 6.31.

Table 2: 5G User Equipment (UE) Service Access Categories Configuration

Access Category number	Conditions related to UE	Type of access attempt
0	All	MO signalling resulting from paging
1 (NOTE 1)	UE is configured for delay tolerant service and subject to access control for Access Category 1, which is judged based on relation of UE's HPLMN and the selected PLMN.	All except for Emergency, or MO exception data
2	All	Emergency
3	All except for the conditions in Access Category 1.	MO signalling on NAS level resulting from other than paging
4	All except for the conditions in Access Category 1.	MMTEL voice (NOTE 3)
5	All except for the conditions in Access Category 1.	MMTEL video
6	All except for the conditions in Access Category 1.	SMS
7	All except for the conditions in Access Category 1.	MO data that do not belong to any other Access Categories (NOTE 4)
8	All except for the conditions in Access Category 1	MO signalling on RRC level resulting from other than paging
9	All except for the conditions in Access Category 1	MO IMS registration related signalling (NOTE 5)
10 (NOTE 6)	All	MO exception data
11-31		Reserved standardized Access Categories
32-63 (NOTE 2)	All	Based on operator classification

NOTE 1: The barring parameter for Access Category 1 is accompanied with information that define whether Access Category applies to UEs within one of the following categories:
a) UEs that are configured for delay tolerant service;
b) UEs that are configured for delay tolerant service and are neither in their HPLMN nor in a PLMN that is equivalent to it;
c) UEs that are configured for delay tolerant service and are neither in the PLMN listed as most preferred PLMN of the country where the UE is roaming in the operator-defined PLMN selector list on the SIM/USIM, nor in their HPLMN nor in a PLMN that is equivalent to their HPLMN.
When a UE is configured for EAB, the UE is also configured for delay tolerant service. In case a UE is configured both for EAB and for EAB override, when upper layer indicates to override Access Category 1, then Access Category 1 is not applicable.

NOTE 2: When there are an Access Category based on operator classification and a standardized Access Category to both of which an access attempt can be categorized, and the standardized Access Category is neither 0 nor 2, the UE applies the Access Category based on operator classification. When there are an Access Category based on operator classification and a standardized Access Category to both of which an access attempt can be categorized, and the standardized Access Category is 0 or 2, the UE applies the standardized Access Category.

NOTE 3: Includes Real-Time Text (RTT).

NOTE 4: Includes IMS Messaging.

NOTE 5: Includes IMS registration related signalling, e.g. IMS initial registration, re-registration, and subscription refresh.

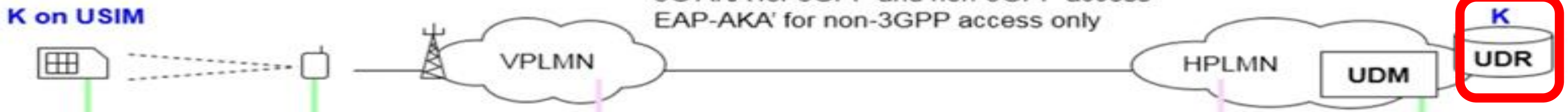
NOTE 6: Applies to access of a NB-IoT-capable UEto a NB-IOT cell connected to 5GC when the UE is authorized to send exception data.

P.S. "Mobility" in 5G with Rel. 15 is re-defined and classifying the UE into 4 (four) Categories of Mobility (namely UEs that are "Stationary", "Nomadic" (within a constrained area) and WAN/Mobile as well as introducing IP Anchor node and UE Relay. D.S.

Selected security enhancements

Authentication improvements

2G/3G/4G: authentication done by VPLMN only
5G: both in VPLMN and HPLMN
5G AKA for 3GPP and non-3GPP access
EAP-AKA' for non-3GPP access only



When challenged, calculate response, NAS/AS keys, verify serving network.

UE authentication: verify UE response

UE authentication: verify UE response

Generate authentication vector(s) upon serving node(s) request(s).

Identity protection improvements

2G/3G/4G: occasionally network asks UE to send permanent id (IMSI) unencrypted over the air
5G: permanent id (SUPI) never sent unencrypted over the air interface

- HPLMN id unencrypted to allow routing of requests VPLMN → HPLMN
- SUCI de-concealment done by UDM in HPLMN using HPLMN private key

AKA	Authentication and Key Agreement
AS	Access Stratum
EAP	Extensible Authentication Protocol
IMSI	International Mobile Subscriber Identity
NAS	Non-Access Stratum
SUCI	Subscription Concealed Identifier
SUPI	Subscription Permanent Identifier
UDR	Unified Data Repository
USIM	Universal Subscriber Identity Module

URSP - UE Route Selection Policy URSP

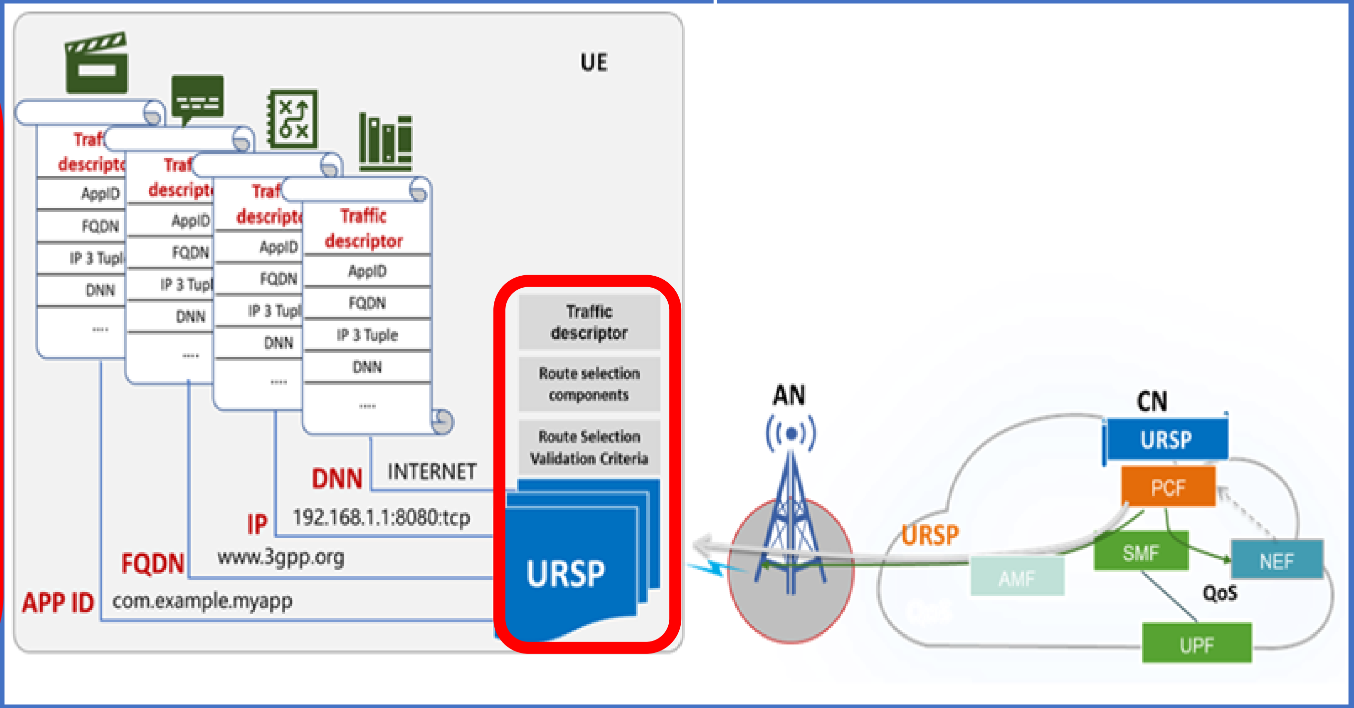
The URSP is defined and is a set of one or more URSP rules, where a URSP rule is composed of:

a) A precedence value of the URSP rule identifying the precedence of the URSP rule among all the existing URSP rules;

b) A traffic descriptor, including either:
  1) match-all traffic descriptor; or
  2) at least one of the following components:
    A) one or more application identifiers;
    B) one or more IP 3 tuples: Destination/ 1. IP Address 2. Port nr, & 3. the Protocol
    C) one or more non-IP descriptors, i.e. destination information of non-IP traffic;
    D) one or more DNNs;
    E) one or more connection capabilities; and
    F) one or more domain descriptors, i.e. destination FQDN(s) or a regular expression as a Domain Name matching criteria; and

c) one or more route selection descriptors each consisting of a precedence value of the route selection descriptor and either
  1) one PDU session type and, optionally, one or more of the followings:
    A) SSC mode;
    B) 1 or more S-NSSAIs;
    C) 1 or more DNNs;
    D) Void;
    E) preferred Access Type;
    F) Multi-Access Preference;
    G) a Time Window; and
    H) Location Criteria;

  2) non-seamless non-3GPP offload indication; or
  3) 5G ProSe Layer-3 UE-to-network relay offload indication



5G ACT & ACR (Application Context Transfer & Application Context relocation

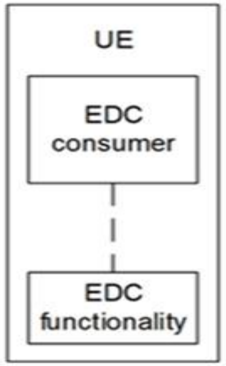


Fig. EDC Funct. in the UE

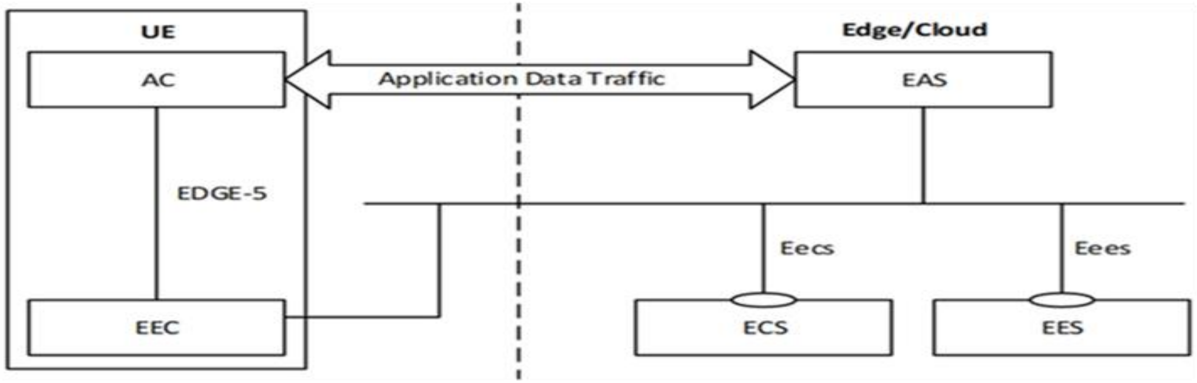


Fig. Archit. For Enabling Edge Applic. - Service-based Represent

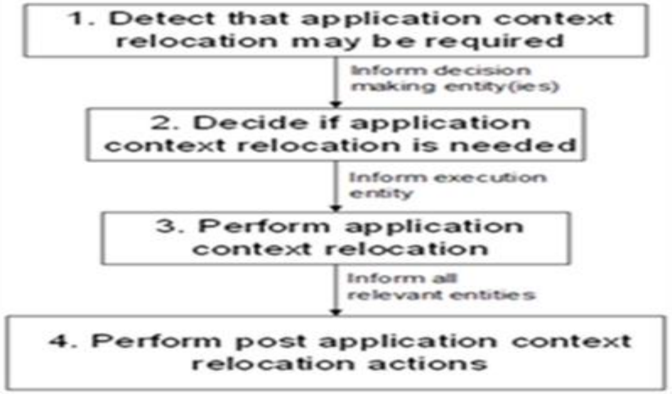


Fig. High level overview of ACR (Application Context Relocation)

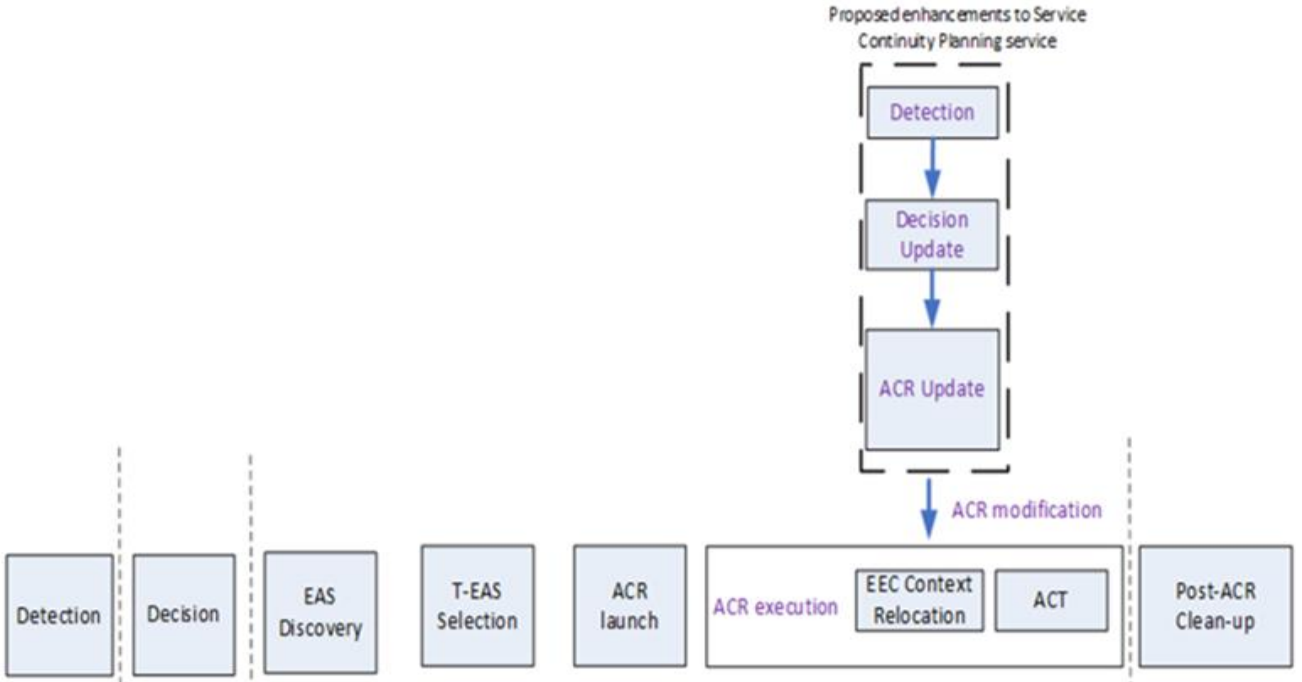


Fig. High-level of proposed ACR update in Service Continuity Planning Enhancement

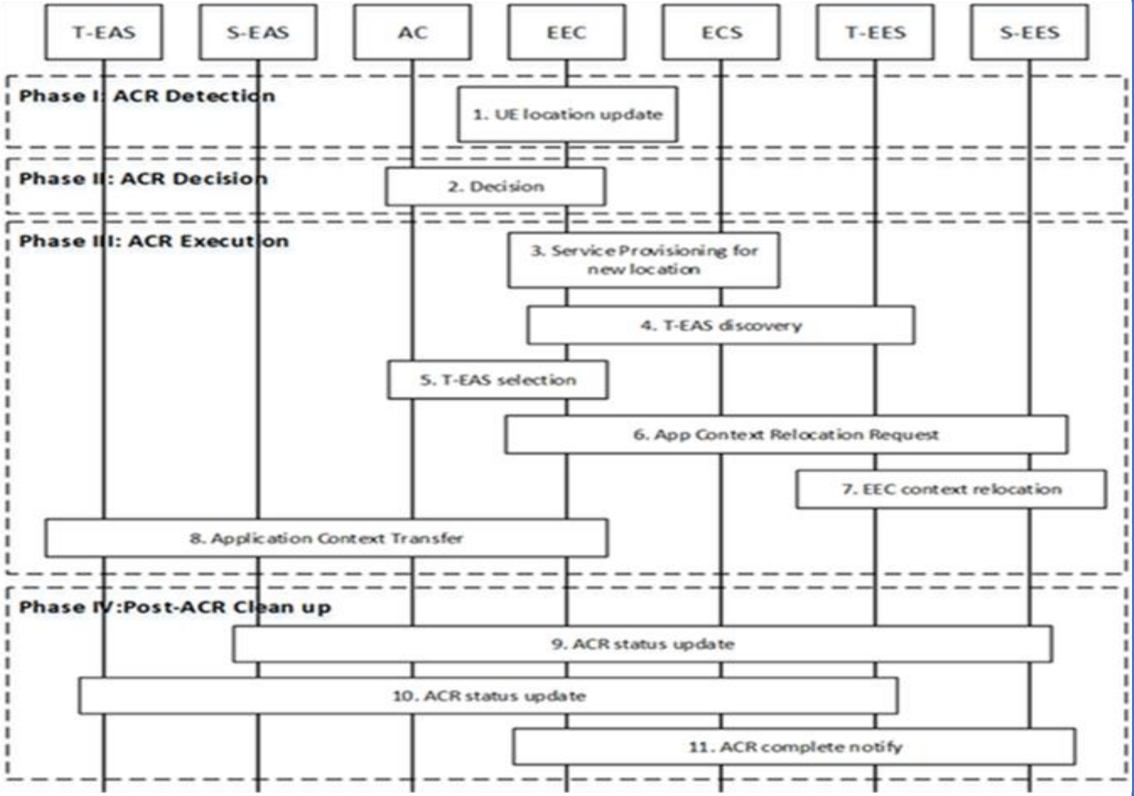


Fig. ACR initiated by the EEC & AC

EASDF - Edge Application Server Discovery Function

Functional Description

The Edge Application Server Discovery Function (EASDF) includes one (1) or more of the following Functionalities:

- Registering to NRF for EASDF Discovery and Selection.
- Handling the **DNS messages** according to the **instruction from the SMF**, including:
  - Receiving DNS message handling Rules and/or **BaselineDNSPattern from the SMF.**
  - Exchanging **DNS messages from the UE**.
  - **Forwarding DNS messages to C-DNS or L-DNS for DNS Query.**
  - Adding **EDNS Client Subnet (ECS) option into DNS Query for an FQDN**.
  - Reporting to the SMF the information related to the received DNS messages.
  - Buffering/Discarding **DNS response messages from the UE or DNS Server**.
- Terminates the **DNS security**, if used.

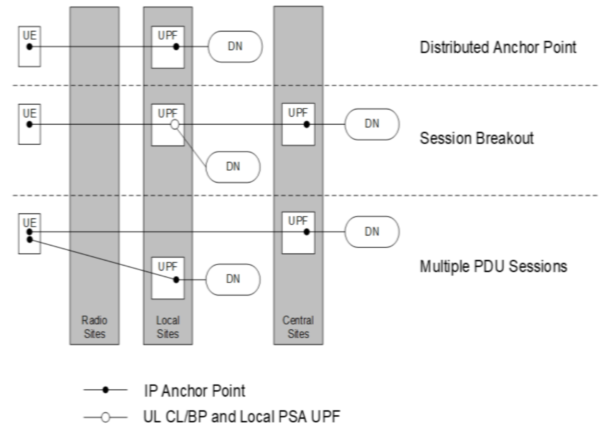


Fig.: 5GC Connectivity Models for Edge Computing

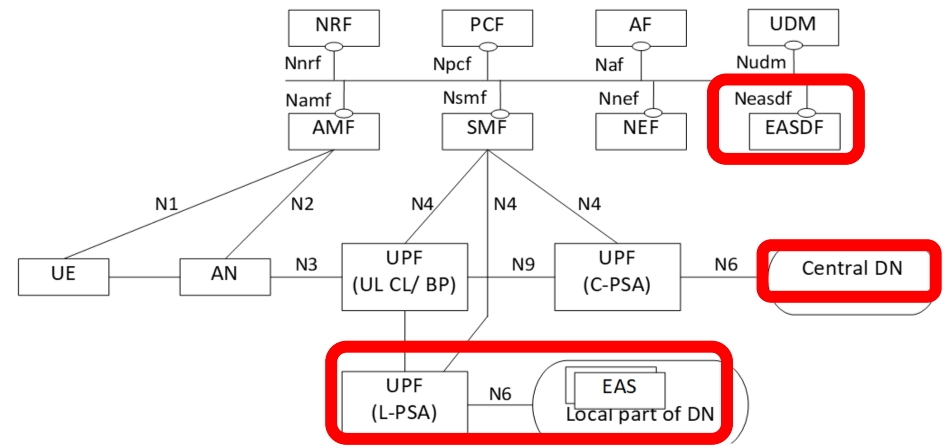


Fig.: 5GS providing Access to EAS with UL CL/BP for Non-Roaming Scenario

The **EASDF has direct User Plane Connectivity** (i.e. without any NAT) with the **PSA UPF over N6** for the transmission of **DNS signalling** exchanged with the UE. **The deployment of a NAT between EASDF and PSA UPF is not supported**.

Multiple EASDF instances may be deployed within a PLMN.

The interactions between 5GC NF(s) and the EASDF take place within a PLMN.

3GPP 5G UE New Services Enablement Clients (UAC - Unified Access Control for Access Identities & Access Categories

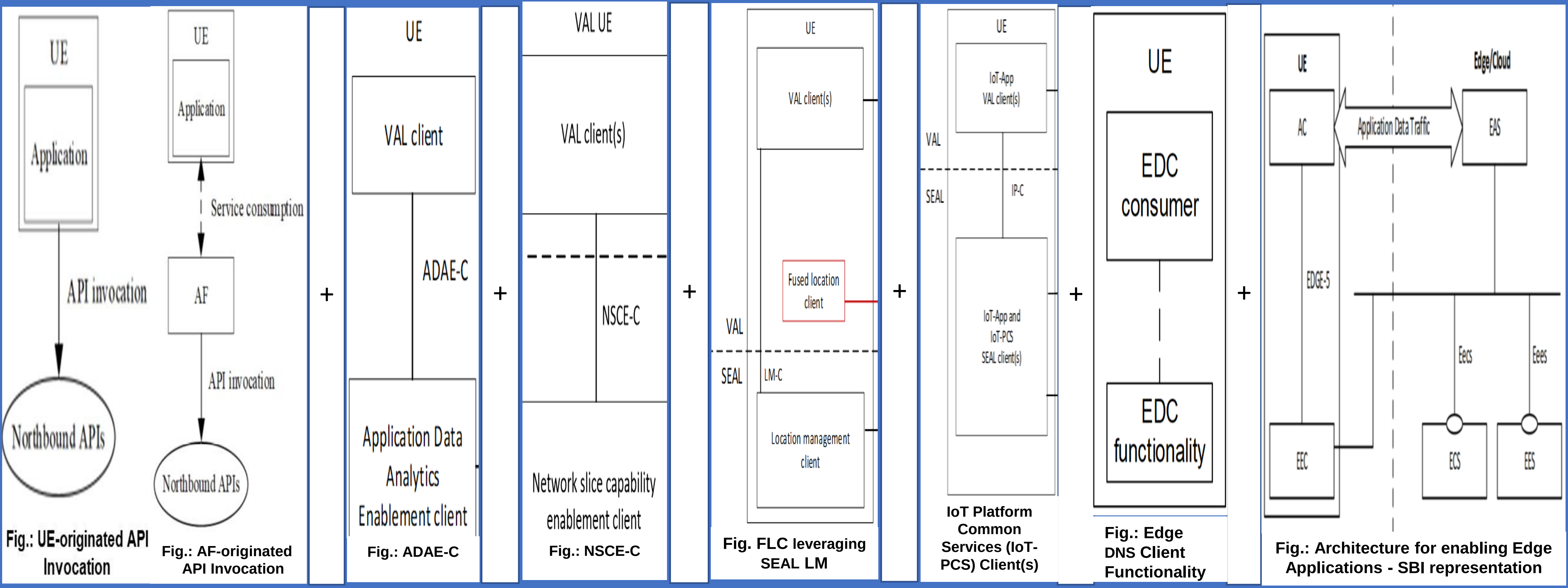


Fig.: UE-originated API Invocation

Fig.: AF-originated API Invocation

Fig.: ADAE-C

Fig.: NSCE-C

Fig. FLC leveraging SEAL LM

IoT Platform Common Services (IoT-PCS) Client(s)

Fig.: Edge DNS Client Functionality

Fig.: Architecture for enabling Edge Applications - SBI representation

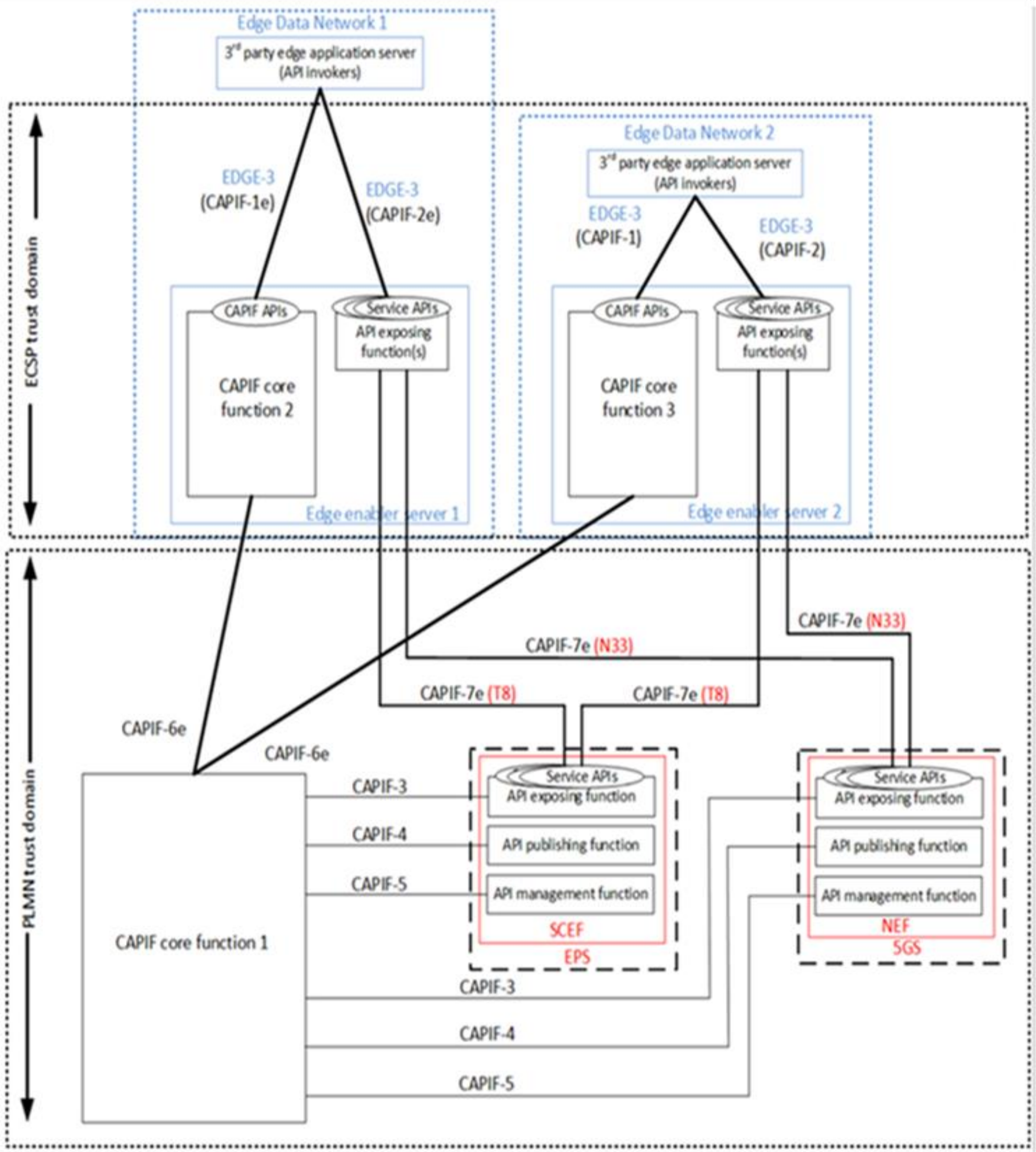


Fig. EES supporting Distributed CAPIF Functions

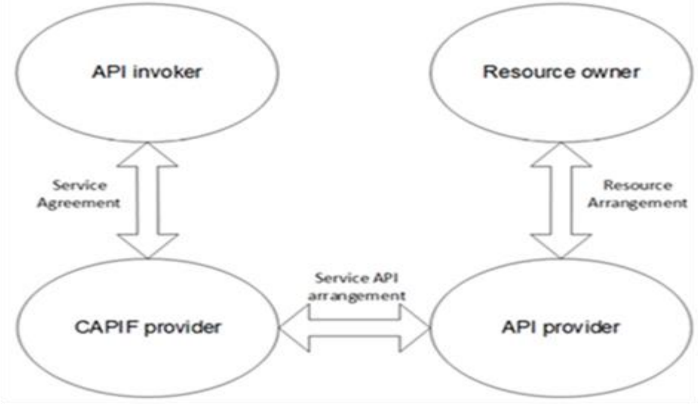


Fig. Business Relationship in SNA

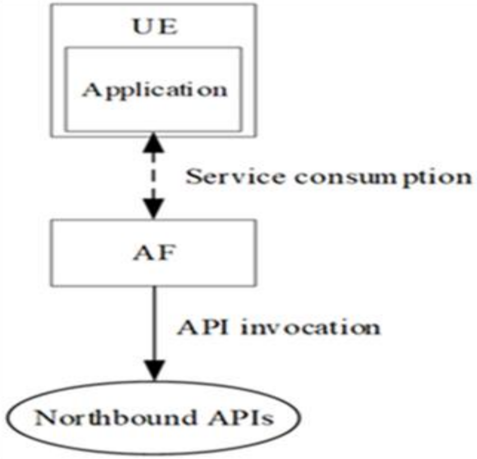


Fig. AF-originated API Invocation

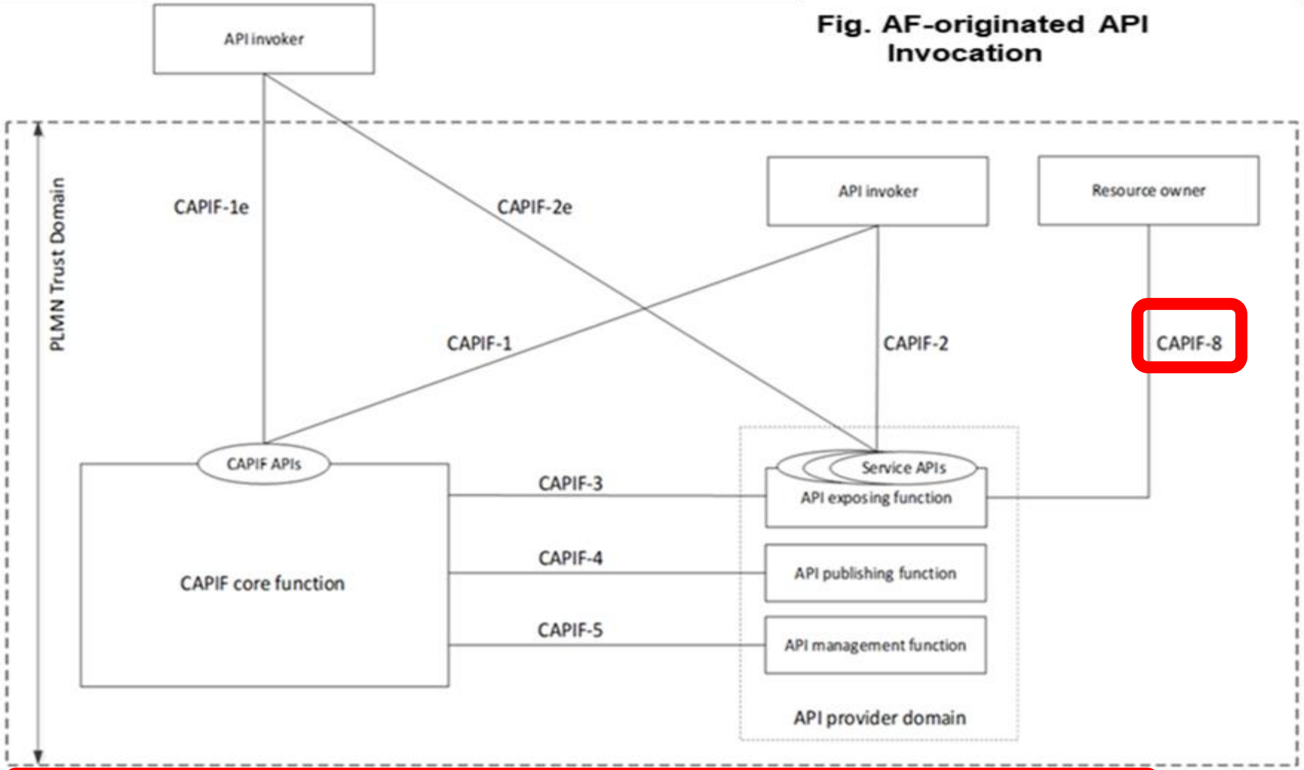


Fig. CAPIF AEF (API Expos. Funct.) for obtaining User Consent via CAPIF-8

1. Enabling Applications/Services Exposure Frameworks

CAPIF-6 and CAPIF-6e Reference Points connect two CAPIF Core Functions located in the same or different PLMN Trust Domains, respectively.

The reference points allows API invokers of a CAPIF Provider to utilize the Service APIs from the 3rd Party CAPIF Provider or another CAPIF Provider within trust domain.

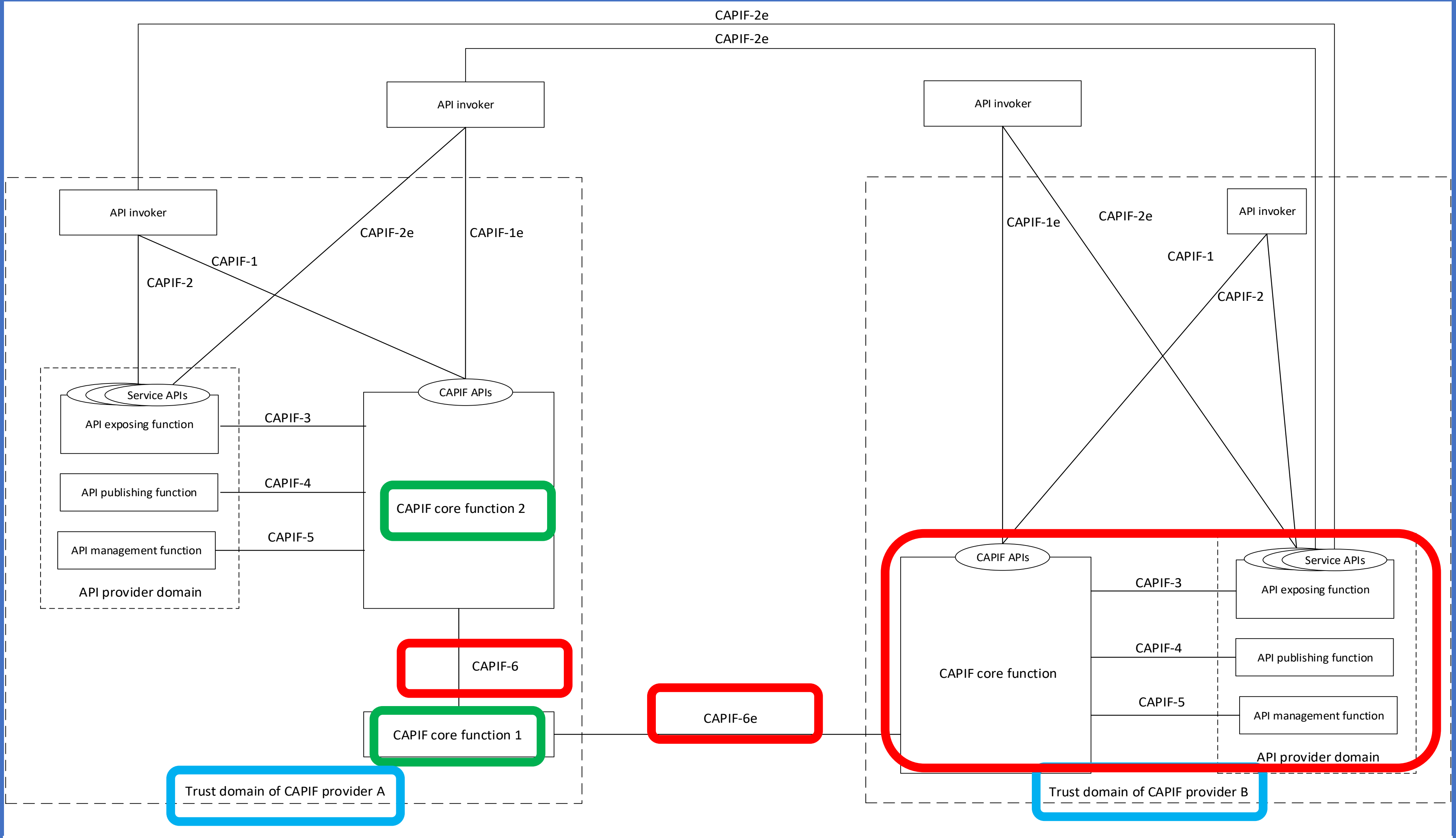


Figure: CAPIF Interconnection Functional Model

The API Invoker supports several Capabilities such as supporting

- the Authentication and obtaining Authorization and Discovering using CAPIF-1/CAPIF-1e Reference Point as defined in 3GPP TS CAPIF and
- invoking the Service APIs using CAPIF-2/CAPIF-2e Referenced Point as defined in 3GPP TS CAPIF e.g. the T8 Interface as defined in GPP TS CAPIF NAPS or the NEF Northbound Interface as defined in 3GPP TS CAPIF NAPS.

5G System can host a PDL Function (PDLF) in the 5GS CN Control Plane (CP) containing the Operational elements shown in the figure below providing an enhancement to 3GPP 5G CN stack related to Security & Authentication, provided within the Secure envelope of 3GPP Systems via a New (SBI) NF Interface (*Npdlf) using* HTTP or JSON to communicate with the CP message bus.

Orchestration of the PDLF should follow stringent Design Guidelines in order not to break the Paradigm of Distributed Ledgers.
The implication is that an ETSI-MANO Orchestration, when applied to a PDL, may remain Centralized in Context, but Implemented in a Distributed manner.

Selected Federated Data Management UCs or Scenarios, which could be benefited from the use of PDL Technology &/or introduce New Requirements for use of set of relatively sequential stages such as **Data Collection, Data Storing, Data Computing, Data Sharing, & Data Visualization**.

For each Stage, Multiple Organizations could participate & have their own Data, e.g., generated from ubiquitous Devices deployed for different Applications such as IIoT, Connected Vehicles, etc.

A Data Pipeline (e.g. Data Pipeline A & Data Pipeline B) starts with Data Collection from devices, but it could complete in different places in the Networking System.

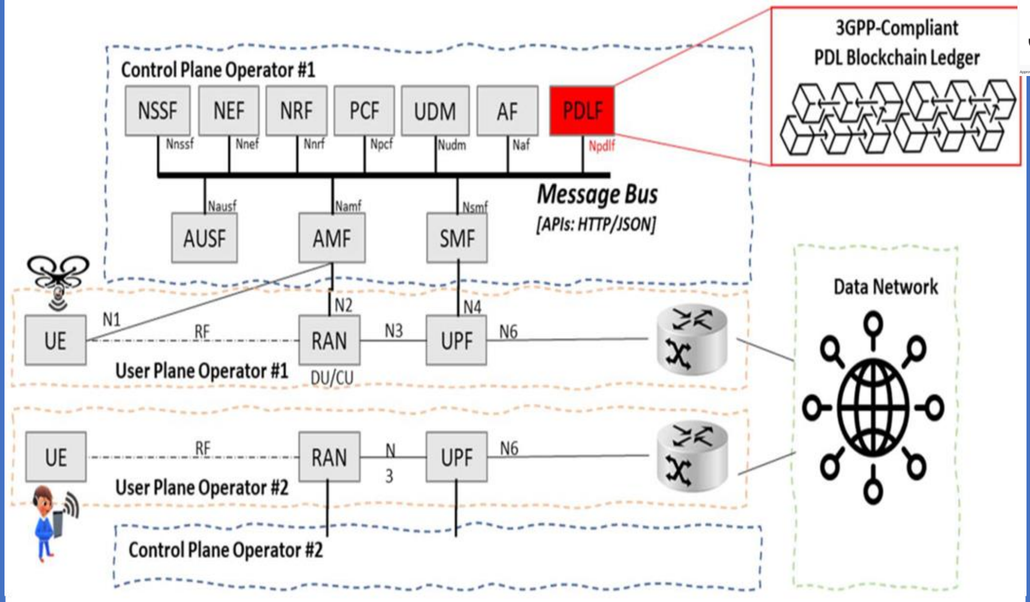


Fig.: 3GPP Architecture and the New Network Function (NF) PDLF on 5G CN CP

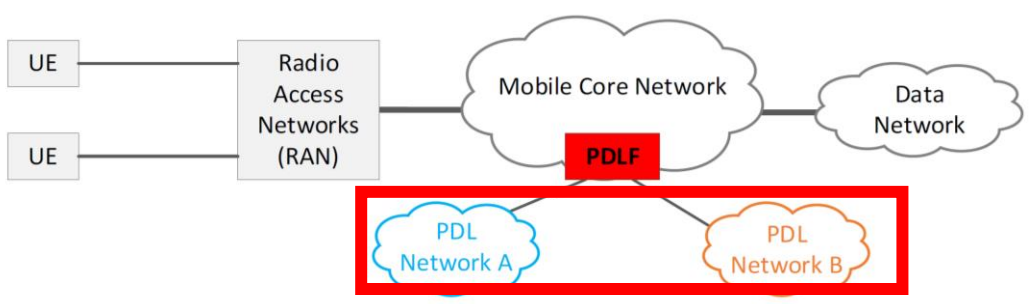


Figure : PDL Function in Mobile Core Networks (Source: Adapted from ETSI GR PDL 010 [9])

Table 3-1: Comparison of Ricardian and Smart Contract

Contract Type	Machine-Readable	Human-Readable	Self-Executable
Ricardian Contract	Yes	Yes	No
Smart Contract	Yes	Optional	Yes

5G SBA UPF enhancements for Service Exposure & Group Management for Communication Enhancements

Improving 5CN Capabilities for the 5G specified 4 Service enablement Architectures for New Services

1) **Avoiding Duplicate Data Transfer & Reducing Transmission Path** enabling the 5CN Services directly "Subscribe/Unsubscribe" on UPF Services for QoS Monitoring Latency Report,

2) Retrieving the UPF original status or Real-Time Service Flow Information in NWDAF, e.g., to facilitate Data Collection & Analysis considering efficient sampling intervals for the different Services.

3) UPF Event Exposure e.g. for 5G IoT Solutions require interfacing of UPF to NEF/Local NEF for Network Information Exposure to an Application Server (e.g. in **IoT-PCS** (*IoT Platform Common Services*) servers enabling a set of Applications deployed using corresponding Servers (IoT-App), which may belong to different verticals & further insights into Scenarios in which an IoT Platform interfaces with the 5G CN to request future Background Data Transfer (BDT) Policies on behalf of IoT Servers.

While the UPF is in the role of "Consumer" of the 5G CN Services, i.e. the UPF can register its NF Profile in the 5G CN with related ***Nupf Service Information*** & does not describe Services provided by the UPF itself.

The 5GC potential enhancements on *Generic Group Management, Exposure & Communication enhancements* (that can be specifically utilized in Slicing & equivalent NPN/SNPNs inter-operability & **roaming, etc.), aim to enhance Group Attribute Management & Group Status Event Reporting, Set/Modify the Group Attributes as Provisioning of Service Area or QoS Applicable to each UE of a given group;** Subscribe to Group Status Event Reporting for the Event "Newly Registered or (De)-Registered Group Member", Whether & How to enhance NEF Exposure Framework to enable Capability Exposure for Provisioning of Traffic Characteristics & Monitoring of Performance Characteristics Applicable to each UE of a given group, Support Group Communication for a 5G VN, which supports multiple SMFs, including support of SMF redundancy for reliability of the 5G VN Group Communication.

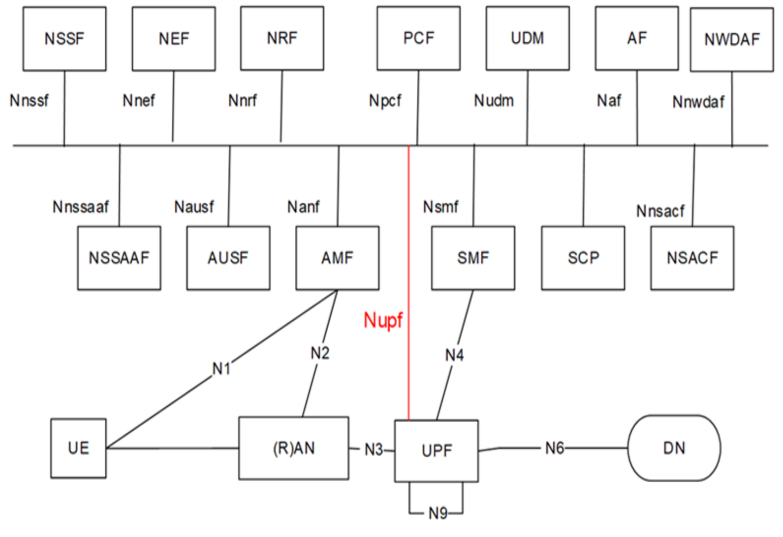


Figure: 5G System Architecture with Service-based UPF

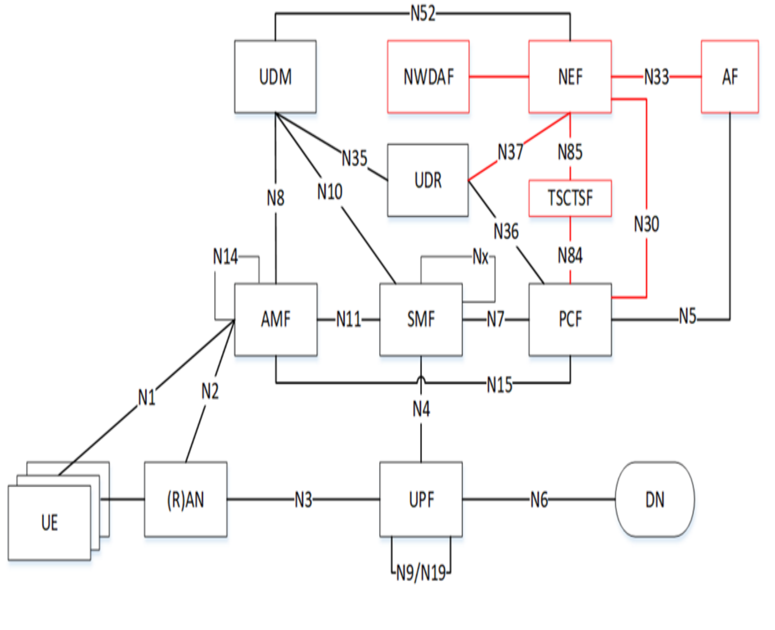


Figure: 5G System Architecture to support Connection Management for a Group

AEF Capabilities

Architecture for enabling E2E Edge Services

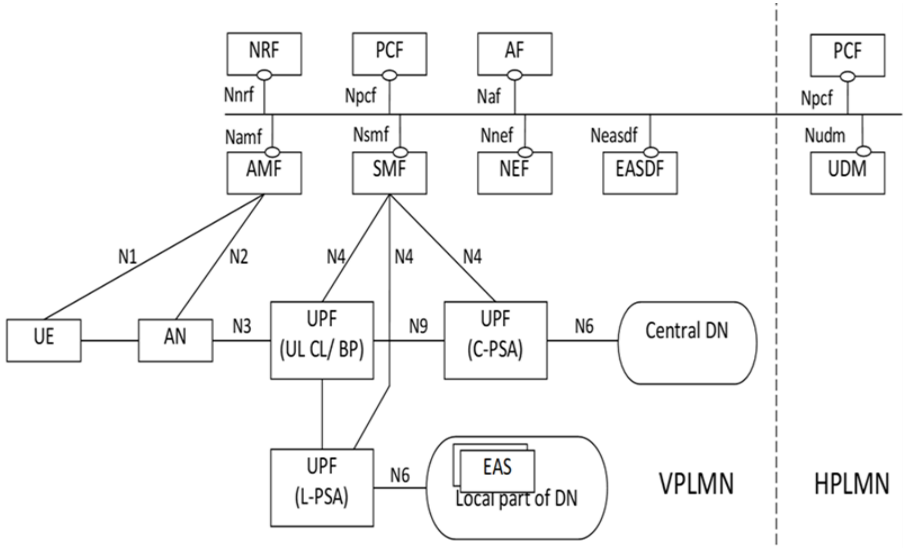


Fig.: 5G System providing access to Edge Application Server (EAS) with Data Traffic split to Local and/or Central DN scenario

GSM Association Non-confidential
Official Document OPG.02 - Operator Platform Telco Edge Requirements

GSMA

Operator Platform Telco Edge Requirements
Version 1.0
29 June 2021

This is a Non-binding Permanent Reference Document of the GSMA

The OPG believes that, for Operators to develop a Federated Edge Computing Platform such as the OP, *Requirements must be enforceable in Contracts by a Published Set of Standards.*

To this end, the OPG proposes selecting ETSI ISG MEC and 3GPP to provide a Standard Reference for an Edge Service End to End (E2E) definition.

We note that 3GPP EDGEAPP Architecture and ETSI ISG MEC Architecture could complement each other in a way that is acceptable to OPG.

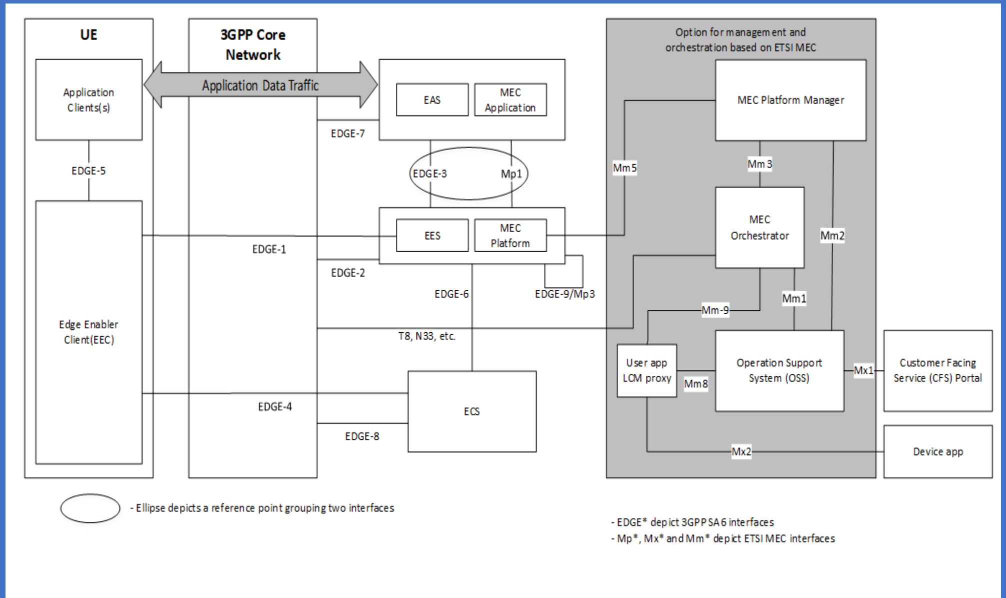


Figure |: Relationship between EDGEAPP and ETSI MEC architectures

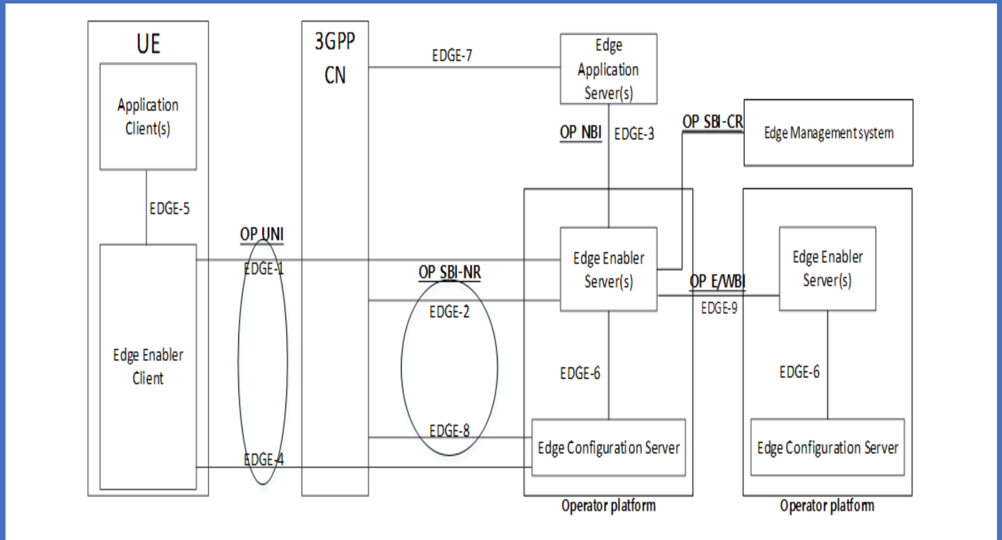


Figure : Relationship between EDGEAPP architecture and GSMA OPG reference architecture

Relationship of Edge Computing Service Providers (ECSPs), PLMN Operators, Application Service Providers (ASPs) and End Users, taking Federation and Roaming into account.

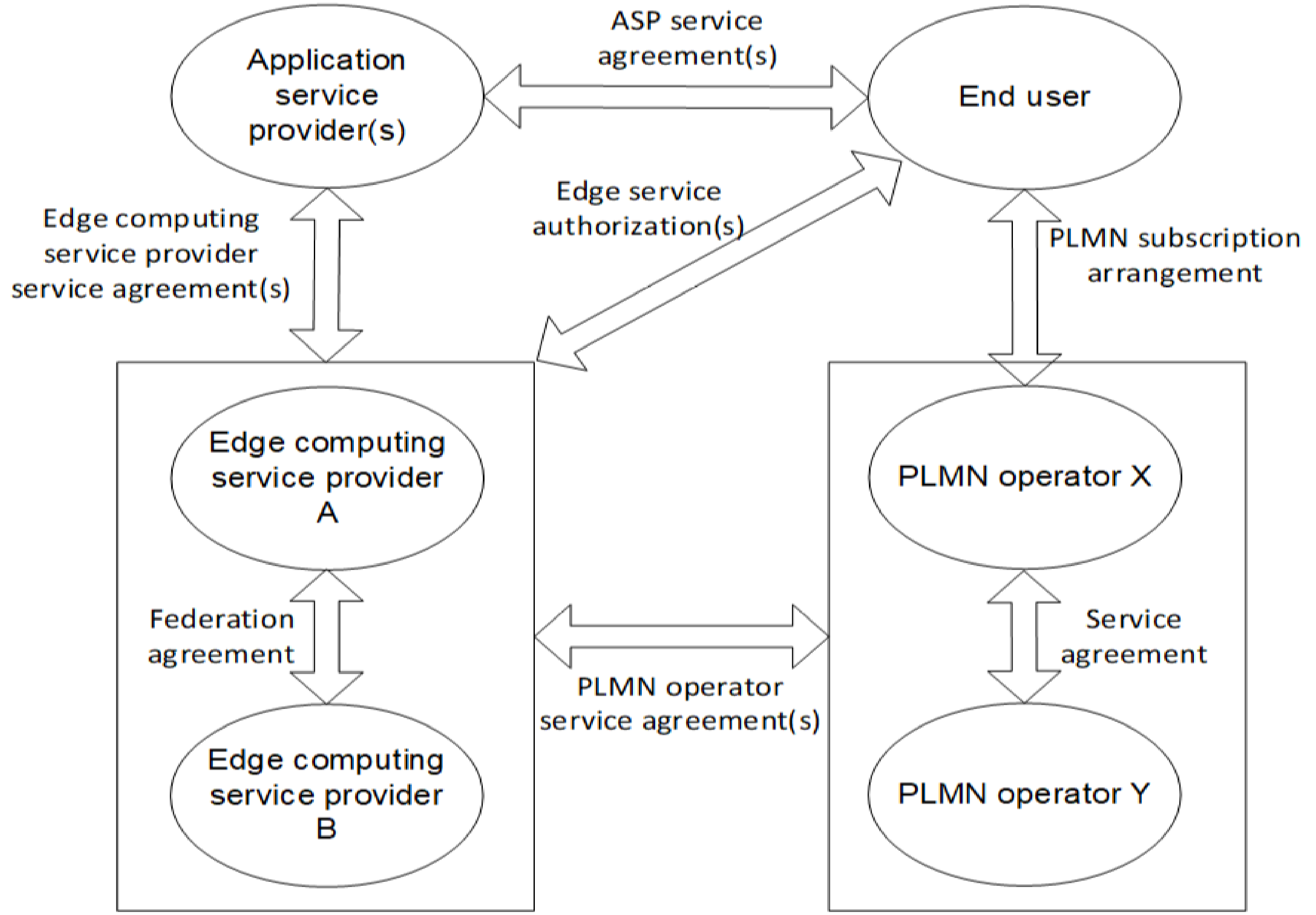


Figure : Relationships involved in edge computing service – federation and roaming

Enhanced EDGEAPP Architecture for enabling Edge Applications in "5G Advanced"

Table Mapping of solutions to key issues

	KI #1	KI #2	KI #3	KI #4	KI #5	KI #6	KI #7	KI #8	KI #9	KI #10	KI #11	KI #12	KI #13	KI #14	KI #15	KI #16	KI #17	KI #18	KI #19	KI #20
Sol #1	x																			
Sol #2							x													
Sol #4						x				x										
Sol #5						x				x										
Sol #6			x																	
Sol #7			x																	
Sol #8		x																		
Sol #9														x						
Sol #10															x					
Sol #11		x			x															
Sol #12			x									x								
Sol #13						x				x										
Sol #14										x										
Sol #15								x						x						
Sol #16												x								
Sol #17														x						
Sol #18															x					
Sol #19																			x	
Sol #20	x																			
...																				

Enhanced EDGEAPP Architecture for enabling Edge Applications

As illustrated in the Figs 1 & 2 below related to Edge Services in V2X and AR/VR Use Cases (as part of the ongoing discussions for enhancements in EDGEAPP Architecture foreseen in "5G Advanced" release (Ref. 3GPP, 5G Advanced, March 2022), an **Edge Service or an EAS** *(Edge Application Server, e.g. V2X Server)* can be provided via different **EDNs** (*Edge Data Networks*) deployed by different **EES** (*Edge Enabling Server*) **ECSPs** (*Edge Computing Service Providers*).

Each ECSP may not have the required Infrastructure to install the EAS in every EDN due to Financial, Regulatory and Operation constraints.

A User can access the same Edge Service served by different **EASs,** which are registered to different **EESs** (*Edge Enabling Servers*) and deployed by different **ECSPs**, which have a Service Level Agreement (**SLA**) to share Edge Services.

These **ECSPs** can deploy **EESs** to serve different Mobile Networks (**PLMNs**) or different Coverages of the same **Mobile Network (PLMN**).

Furthermore, the Target EDN (T-EDN) and Source EDN (S-EDN) are operated by different **ECSP** which may not have **SLA** with each other, then the **S-EES** may not be able to communicate with a **T-EES** (discovered from **ECS**) due to lack of **SLA**.

Unfortunately, in **Rel.17** this failure may only be detect upon **EDGE-9** interaction.

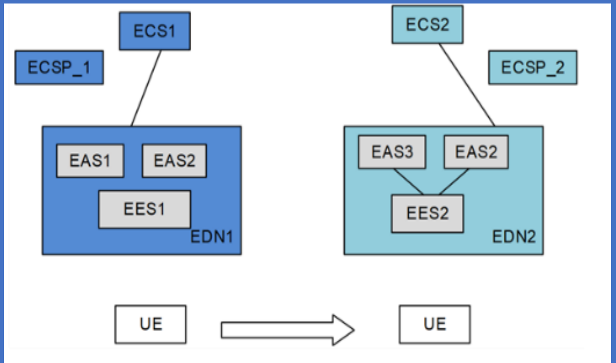


Fig 1.: EAS (Edge Application Server) deployed by different ECSPs (Edge Computing Service Providers)

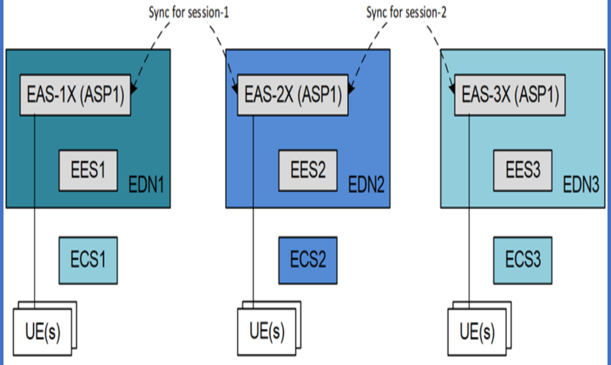


Fig. 2: EAS (Edge Application Server) with same Service deployed by same ASP (Application Service Provider) in different EDNs (Edge Data Networks)

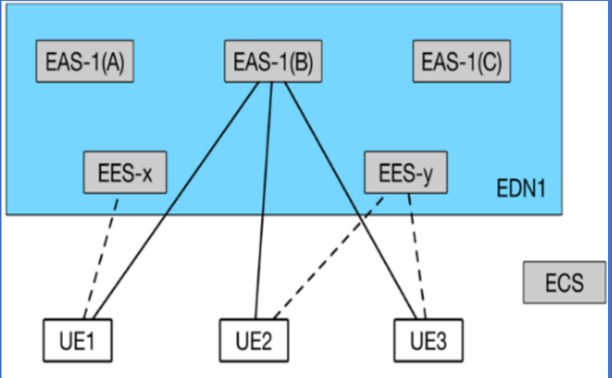


Fig. 3.: Several EAS (Edge Application Server) with same Service deployed in different locations in the same EDN (Edge Data Network)

Dependent on the Use Case (UC), the **EEL** (*Edge Enabling Layer*) may apply different additional criteria to determine this **common EAS.**

E.g., it could be desirable to determine the **EAS** so that the **Latency** for all the **ACs** in the session is approximately the same or that the **Latency** for a specific **AC** is minimized.

There is further utilization of Capabilities related to **EEL** (*Edge Enabling Layer*) and **AEF** (*API Exposing Function*) and **5G NDL** (*Network Data Layer)* specified and stored **NF's Application Context** (*ACR/ACT, Application Context Relocation/Application Context Transfer*) for assuring Service Continuity between **S-EAS** and **T-EAS**) as well as *Data Traffic split rendering* between **EASs** and **CAS** (*Cloud Application Server*).

Table: KPI Table for Additional High Data Rate and Low Latency Service

Use Cases	Characteristic parameter (KPI)			Influence quantity		
	Max allowed end-to-end latency	Service bit rate: user-experienced data rate	Reliability	# of UEs	UE Speed	Service Area (note 2)
Cloud/Edge/Split Rendering (note 1)	5 ms (i.e. UL+DL between UE and the interface to data network) (note 4)	0,1 to [1] Gbit/s supporting visual content (e.g. VR based or high definition video) with 4K, 8K resolution and up to120 frames per second content.	99,99 % in uplink and 99,9 % in downlink (note 4)	-	Stationary or Pedestrian	Countrywide
Gaming or Interactive Data Exchanging (note 3)	10ms (note 4)	0,1 to [1] Gbit/s supporting visual content (e.g. VR based or high definition video) with 4K, 8K resolution and up to120 frames per second content.	99,99 % (note 4)	≤ [10]	Stationary or Pedestrian	20 m x 10 m; in one vehicle (up to 120 km/h) and in one train (up to 500 km/h)
Consumption of VR content via tethered VR headset (note 6)	[5 to 10] ms (note 5)	0,1 to [10] Gbit/s (note 5)	[99,99 %]	-	Stationary or Pedestrian	-

NOTE 1: Unless otherwise specified, all communication via wireless link is between UEs and network node (UE to network node and/or network node to UE) rather than direct wireless links (UE to UE).
NOTE 2: Length x width (x height).
NOTE 3: Communication includes direct wireless links (UE to UE).
NOTE 4: Latency and reliability KPIs can vary based on specific use case/architecture, e.g. for cloud/edge/split rendering, and may be represented by a range of values.
NOTE 5: The decoding capability in the VR headset and the encoding/decoding complexity/time of the stream will set the required bit rate and latency over the direct wireless link between the tethered VR headset and its connected UE, bit rate from 100 Mbit/s to [10] Gbit/s and latency from 5 ms to 10 ms.
NOTE 6: The performance requirement is valid for the direct wireless link between the tethered VR headset and its connected UE.

Enablement of Service APIs exposed by EAS

EAS Service API enablement in the EDGEAPP Architecture for KI#2 specific requirements in this clause, the Solution #X: *"EAS Service API enablement using CAPIF" is further specified.*

This solution is based on Architectural requirements to support ***EAS Service APIs*** in the **EDGEAPP Rel. 18 (5G Advanced) Architecture.**

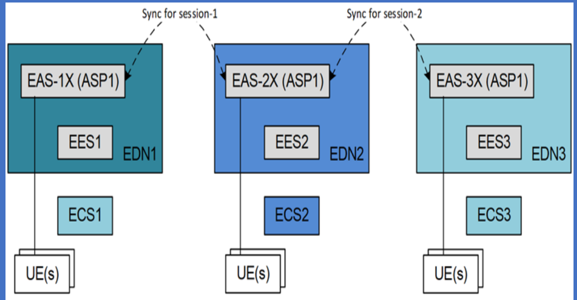


Fig. 2: EAS (Edge Application Server) with same Service deployed by same ASP (Application Service Provider) in different EDNs (Edge Data Networks)

1) EAS Capability Exposure

- ***The Application Layer Architecture shall support Exposure of EAS's Capabilities to the other EASs.***

2) EAS Service API publication

- The Application Layer Architecture shall support EAS to publish its exposing Service API information to EES
- The application layer architecture shall support EAS to update the published EAS Service API information on the EES.

3) EAS Service API discovery

- ***The Application Layer Architecture shall provide Mechanisms for an EAS to discover Available EAS Service APIs.***

4) Subscription service

- The Application Layer Architecture shall provide Subscription and Notification Mechanisms enabling an EAS to receive changes in dynamic information of EAS Service APIs from an EES.
- The application layer architecture shall provide subscription and notification mechanisms enabling an EAS to receive changes in availability of EAS Service APIs from an EES.

Table : Service API publish request

Information element	Status	Description
API publisher information	M	The information of the API publisher may include identity, authentication and authorization information
Service API information	M	The service API information includes the service API name, service API type, communication type, description, Serving Area Information (optional), AEF location (optional), interface details (e.g. IP address, port number, URI), protocols, version numbers, and data format, (new) Service KPI.
Shareable information	O (see NOTE)	Indicates whether the service API or the service API category can be published to other CCFs. And if sharing, a list of CAPIF provider domain information where the service API or the service API category can be published is contained.
NOTE: If the shareable information is not present, the service API is not allowed to be shared.		

Table : Onboard API invoker response

Information element	Status	Description
Onboarding status	M	The result of onboarding request i.e., success indication is included if the API invoker is granted permission otherwise failure.
Enrolled information	O (see NOTE 1)	Information from the provisioned API invoker profile which may include information to allow the API invoker to be authenticated and to obtain authorization for service APIs
Service API information	O (see NOTE 2)	The service API information includes the service API name, service API type, communication type, description, Serving Area Information (optional), AEF location (optional), interface details (e.g. IP address, port number, URI), protocols, version numbers, and data format, (new) Service KPI.
Reason	O (see NOTE 3)	This element indicates the reason when onboarding status is failure.
NOTE 1: Information element shall be present when onboarding status is successful. NOTE 2: Information element may be present when onboarding status is successful. NOTE 3: Information element shall be present when onboarding status is failure.		

Table : ACR request

Information element	Status	Description
Requestor Identifier	M	Unique identifier of the requestor (i.e. EECID or EASID).
Security credentials	M	Security credentials resulting from a successful authorization for the edge computing service.
UE identifier (NOTE 4)	O	The identifier of the UE (i.e. GPSI).
ACR type	M	Indicates whether the ACR is for normal ACR or service continuity planning
Predicted/Expected UE location or EAS service area (NOTE 5)	O	The predicted/expected location information of the UE. The UE location is described in clause 7.3.2 or the predicted/expected EAS service area as described in clause 7.3.3.3
ACR action (NOTE 3)	M	Indicates the ACR action (ACR initiation or ACR determination)
ACR initiation data (NOTE 2)	O	ACR initiation IEs to be included in an ACR request message when ACR action indicates it is ACR initiation request.
> T-EAS Endpoint	M	Endpoint information (e.g. URI, FQDN, IP 3-tuple) of the T-EAS
> DNAI of the T-EAS	O	DNAI information associated with the T-EAS.
> N6 Traffic Routing requirements	O	The N6 traffic routing information and/or routing profile ID corresponding to the T-EAS DNAI.
> EAS notification indication	M	Indicates whether to notify the EAS about the need of ACR.
> S-EAS endpoint (NOTE 1)	O	Endpoint information of the S-EAS
ACR determination data (NOTE 2)	O	ACR determination IEs to be included in an ACR request message when ACR action indicates it is ACR determination request.
> S-EAS endpoint	M	Endpoint information of the S-EAS
NOTE 1: This IE shall be present if the EAS notification indication indicates that the EAS needs to be informed. NOTE 2: Either ACR initiation or ACR determination shall be included corresponding to the ACR action. NOTE 3: This IE shall indicate ACR determination if the request originates from the S-EAS. NOTE 4: This IE shall be present if the request originates from the EEC. NOTE 5: This IE shall be present if the ACR type indicates the ACR procedure is for service continuity planning.		

Table : Session with QoS create request

Information element	Status	Description
EASID	M	The identifier of the EAS
Security credentials	M	Security credentials of the EAS
UE IP address (NOTE 1)	O	The UE IP address.
UE ID (NOTE 1)	O	The identifier of the UE (i.e. GPSI)
UE Group ID (NOTE 1)	O	Identifies a group of UEs (i.e. internal group ID or external group ID)
IP flow description	M	The IP flow description for the application traffic.
Requested QoS reference (NOTE 2)	O	Refers to pre-defined QoS information for the data session between AC and EAS (NOTE 3).
…	…	…

Deployment and Evolution options of EDGEAPP and ETSI MEC Platforms (Informative):

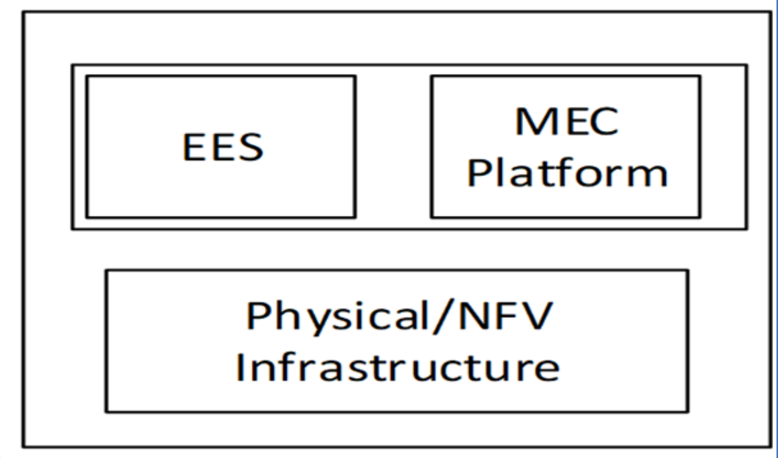


Figure.: EES and MEC Platform as two different AFs on a single Physical//NFV Infrastructure

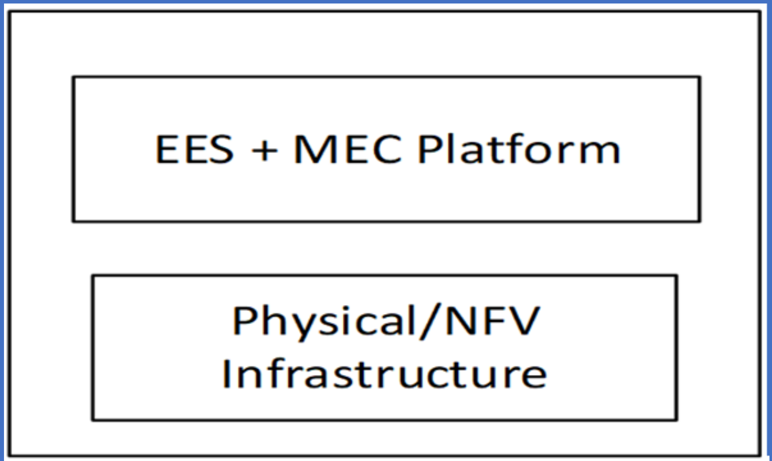


Fig.: EES and MEC Platform as a single AF on a single NFV Infrastructure

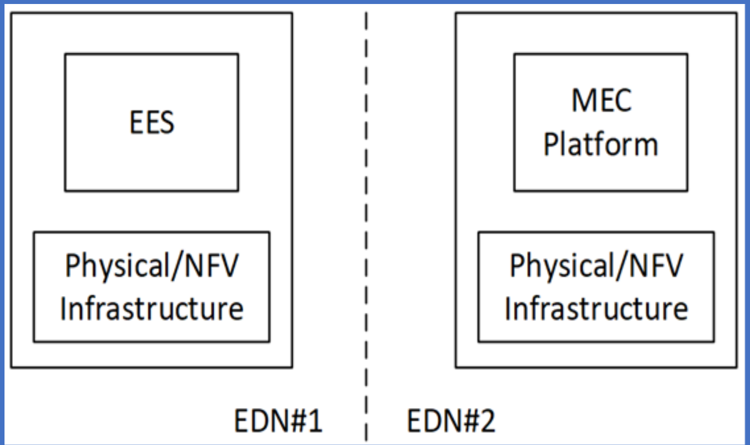


Fig.: EES and MEC Platform as two different AFs on two different EDNs

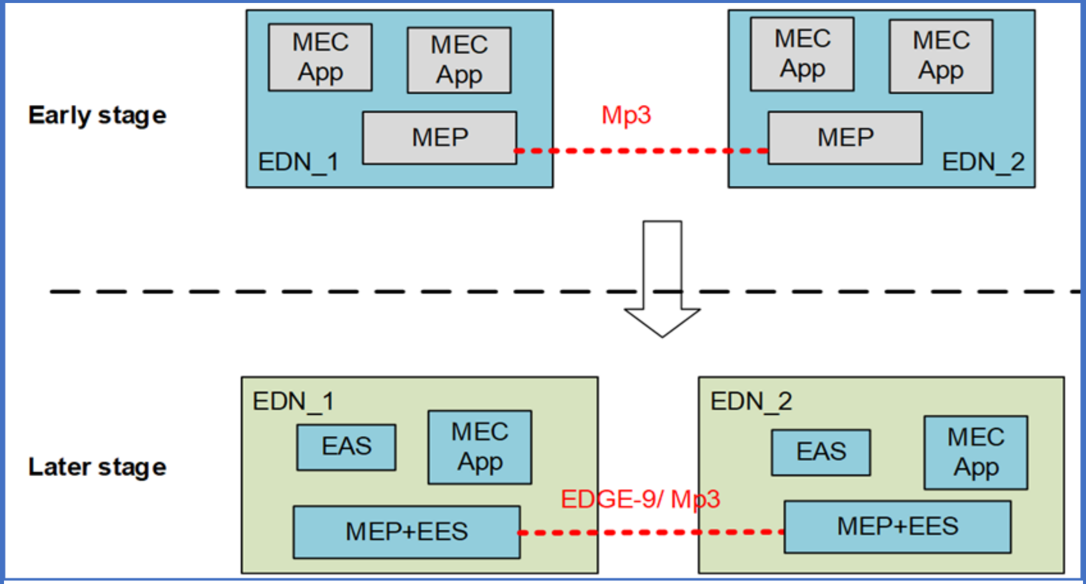


Fig.: Evolution Option #1 - An early stage deployed MEP is enhanced to support the functionality of EES in a later stage

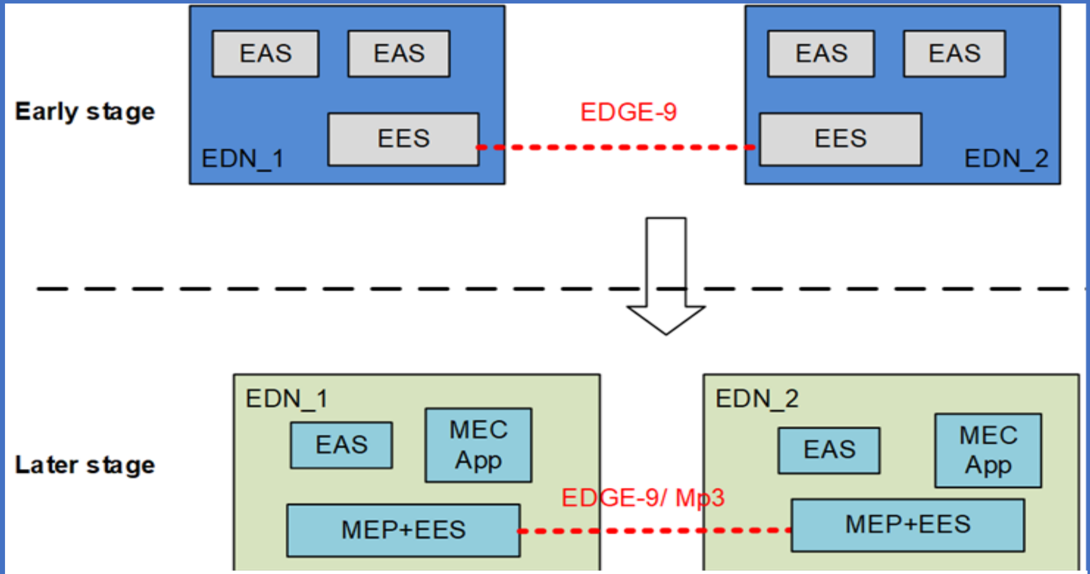


Fig.: Evolution Option #2 - Enhancement of a deployed EES to support functionality of MEP

Slicing

Slicing 1 Enhancements Ph. 3

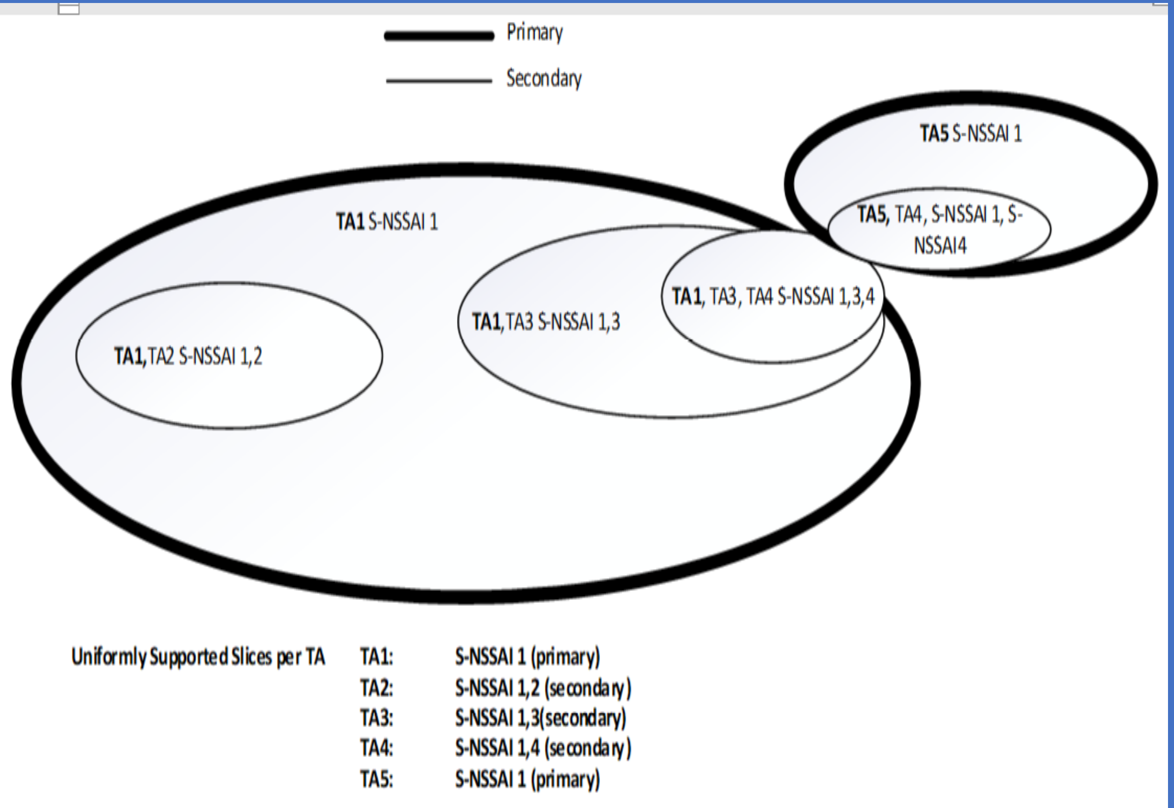


Figure : Example TA topology including Primary and Secondary TAs

1. **Key Issue #1: Support of Network Slice Service Continuity**

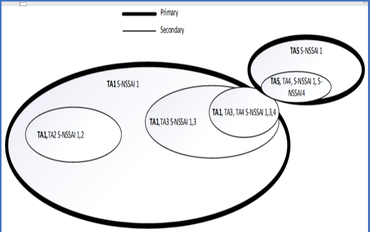
2. **Key Issue #2: Support of providing VPLMN Network Slice Information to a roaming UE**

3. **Key Issue #3: Network Slice Area of Service for Services not mapping to existing TAs boundaries, and Temporary Network Slices**

4. **Key Issue #4: Support of NSAC involving Multi Service Area**

5. **Key Issue #5: Improved support of RAs (Registration Area) including TAs supporting Rejected S-NSSAIs**

6. **Key Issue #6: Improved Network Control of the UE behaviour**



Uniformly Supported Slices per TA
TA1: S-NSSAI 1 (primary)
TA2: S-NSSAI 1,2 (secondary)
TA3: S-NSSAI 1,3(secondary)
TA4: S-NSSAI 1,4 (secondary)
TA5: S-NSSAI 1 (primary)

Figure : Example TA topology including Primary and Secondary TAs

Mapping of Solutions to Key Issues

Table : Mapping of Solutions to Key Issues

Solutions	Key Issues					
	KI#1	KI#2	KI#3	KI#4	KI#5	KI#6
Solution #1: Additional S-NSSAI associated with the PDU session	X					
Solution #2: Slice Re-mapping Capabilities for Network Slice Service Continuity	X					
Solution #3: Support of Network Slice Service continuity using SSC mode 3	X					
Solution #4: PDU Session on compatible network slice	X					
Solution #5: PDU session handover to a target CN with an alternative S-NSSAI support	X					
Solution #6: Extended SoR VPLMN Slice Information transfer to UEs		X				
Solution #7: Enabling awareness of Network Slice availability in VPLMNs		X				
Solution #8: Gracefully network slice termination			X			
Solution #9: Support of a Network Slice with an AoS not matching existing TA boundaries			X			
Solution #10: Associating a validity timer with a temporary slice			X			
Solution #11: Enabling UEs to Request S-NSSAIs not uniformly available			X		X	
Solution #12: Solution for Centralized Counting for Multiple Service Areas and 5GS-EPS Interworking				X		
Solution #13: Hierarchical NSACF Architecture for Maximum UE/PDU Session number control				X		
Solution #14: Maximum Number Distribution in multiple NSACFs				X		

Slicing 2

Enhanced Access to and Support of Network Slice

To improve UL Coverage for High Frequency Scenarios, SUL can be configured so that, the UE is configured with 2 ULs for one (1) DL of the same Cell as depicted on Fig. below:

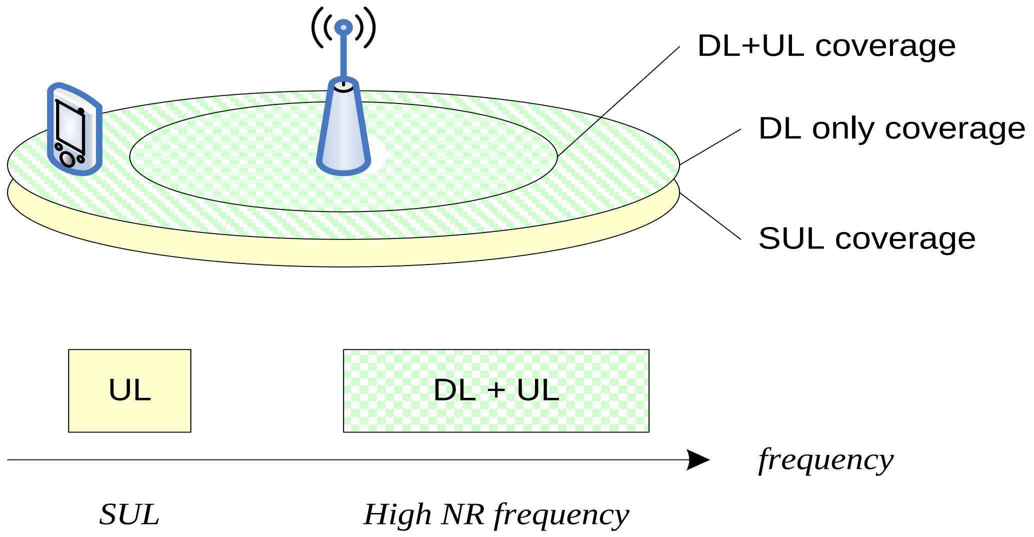


Fig.: Example of Supplementary Uplink (SUL)

Slicing Enhanced Access to and Support for NS
Scenarios 1-3:

1. **When there is a Restriction of Network Slice (SST) to e.g., certain <u>Frequency Bands/Sub Bands, RATs, Geographical Areas, Networks & Applications</u>**

2. When a UE has a <u>Subscription to Multiple Network Slices</u> & these Network Slices are deployed for e.g., Different Frequency Bands/Sub Bands, RATs, Geographical Area & Applications

3. When there is a <u>Preference or Prioritization for a Network Slice (SST) over other Network Slices</u> (SST) e.g. when there are conflicting constraints on Network Slice (SST) Availability.

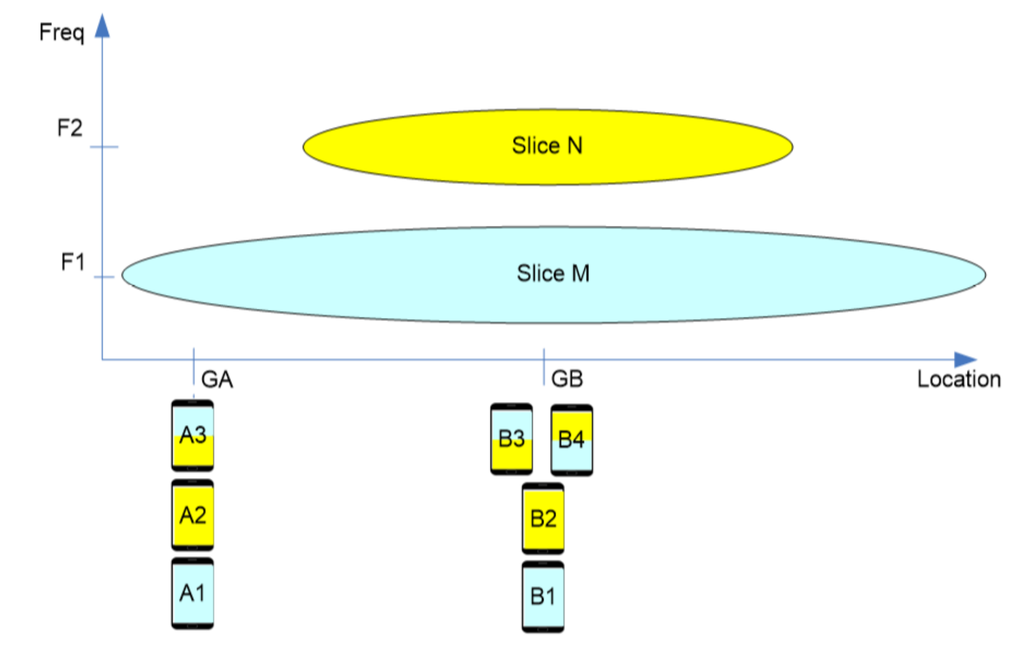


Figure Initial Setup before-power on

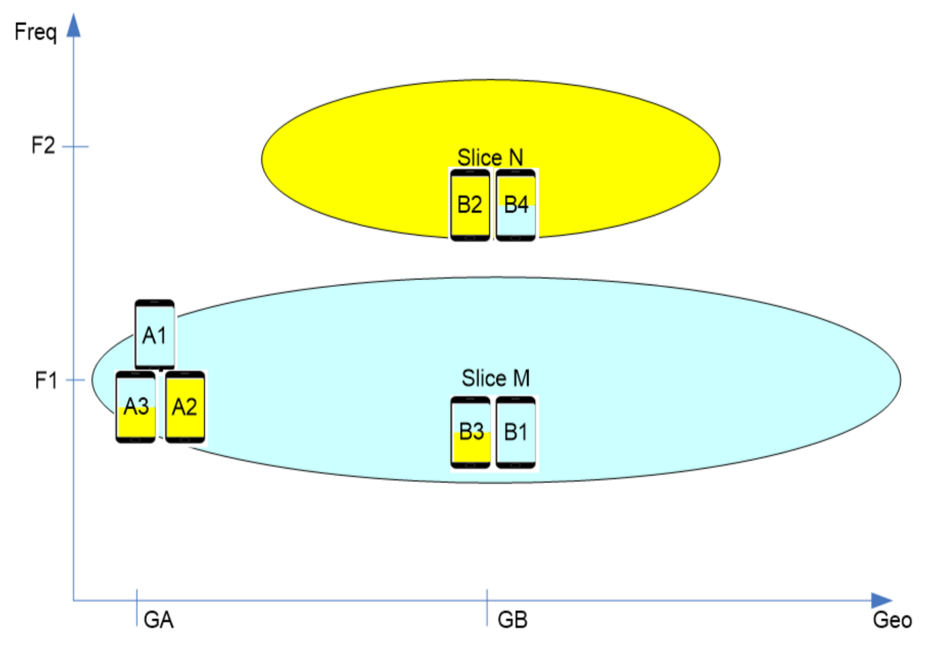


Figure UE status after-power on

Slicing Enhanced Access to and Support for NS

Scenarios 1-3:

1. **When there is a Restriction of Network Slice (SST) to e.g., certain <u>Frequency Bands/Sub Bands, RATs, Geographical Areas, Networks & Applications</u>**

2. When a UE has a <u>Subscription to Multiple Network Slices</u> & these Network Slices are deployed for e.g., Different Frequency Bands/Sub Bands, RATs, Geographical Area & Applications

3. When there is a <u>Preference or Prioritization for a Network Slice (SST) over other Network Slices</u> (SST) e.g. when there are conflicting constraints on Network Slice (SST) Availability.

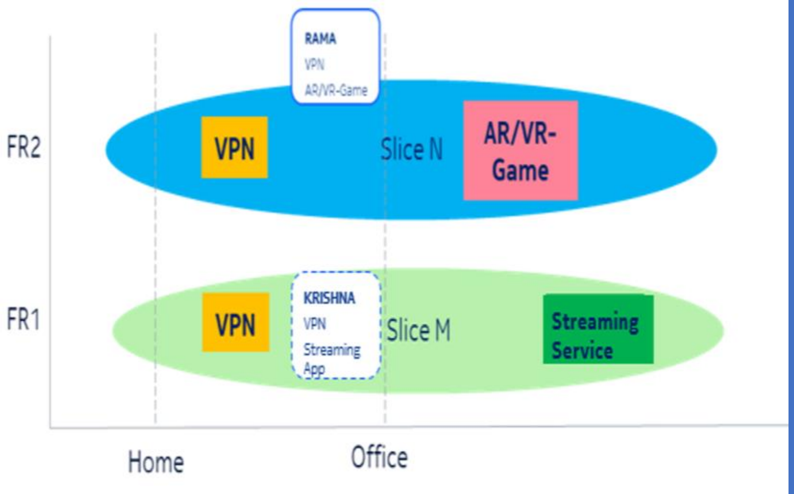


Figure Applications preferred network slices for Rama and Krishna during Workdays (Working Hours)

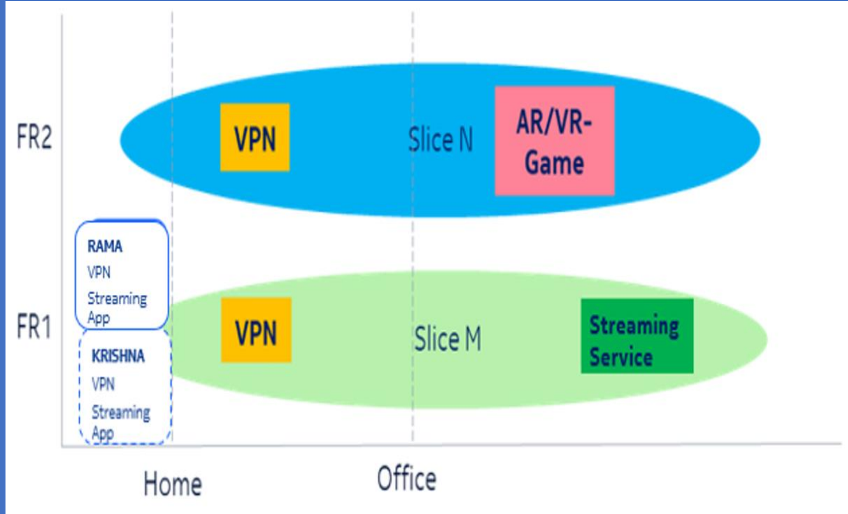


Figure Applications preferred network slices for Rama and Krishna during Evenings (off-Working Hours)

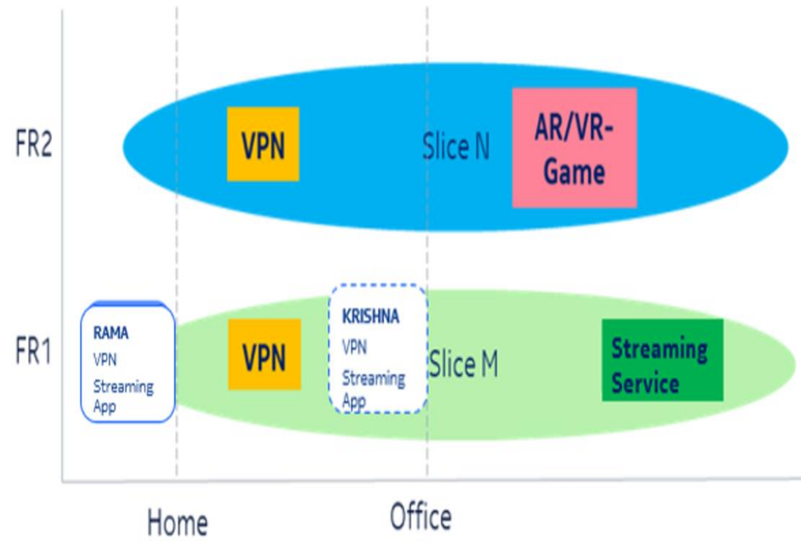


Figure : WFH Scenario for Rama and normal work day for Krishna.

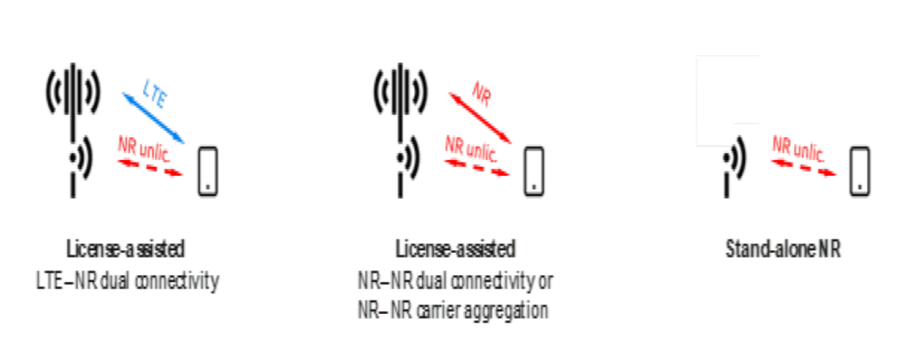


Fig. 3.10. License-assisted (left and middle) and stand-alone (right) operation of NR in unlicensed spectra.

Stand-alone (SA) - NR-U (NR-Unlicensed) connected to 5GC.

This Scenario targets NPN

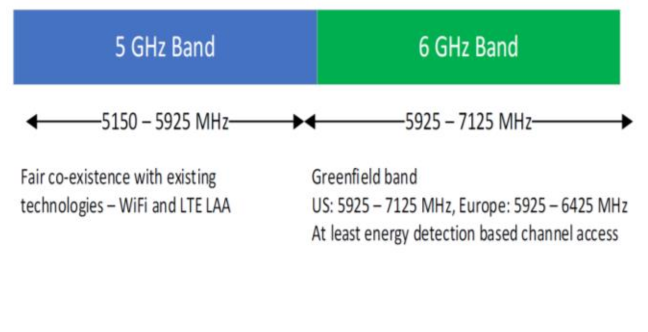


Fig. 3.9. Spectrum priorities for NR-U.

In 3GPP Rel. 16, NR was extended to support operation also in Un-licensed Spectra, with focus on the 5 GHz (5150-5925 GHz) & 6 GHz (5925 – 7150 GHz) bands (Figure 3.9).

- In contrast to LTE, which only supports License-Assisted-Access (LAA) operation in Un-licensed Spectrum,
- NR supports both LAA & Stand-alone (SA) Un-licensed Operation, see Figure 310.

In the case of LAA, a NR carrier in unlicensed spectrum is always operating jointly with a carrier in licensed spectrum, with the carrier in licensed spectrum used for initial access and mobility.

- The licensed carrier can be an NR carrier, but it can also be an LTE carrier. Dual connectivity is used in case of the licensed carrier using LTE. If the licensed carrier is using NR, either dual connectivity or carrier aggregation can be used between the licensed and unlicensed carrier.

In case of SA operation, an NR carrier in Un-licensed spectrum operates without support of a licensed carrier.

Thus, initial access and mobility are handled entirely using unlicensed spectra.

- The 5 GHz band is used by existing Technologies such as Wi-Fi & LTE-based LAA and it was a requirement, for the design of NR-U, or NR in Un-licensed spectrum,

Ref. 5G Americas, 3GPP Rel 16 & 17, & Beyond, Jan 2021: 34

The frequency ranges in which NR can operate according to this version of the specification are identified as described in Table 5.1-1.

Table 5.1-1: Definition of frequency ranges

Frequency range designation	Corresponding frequency range
FR1	410 MHz – 7125 MHz
FR2	24250 MHz – 52600 MHz

NR is designed to operate in the FR2 operating bands defined in Table 5.2-1.

Table 5.2-1: NR operating bands in FR2

Operating Band	Uplink (UL) operating band BS receive UE transmit	Downlink (DL) operating band BS transmit UE receive	Duplex Mode
	F_{UL_low} – F_{UL_high}	F_{DL_low} – F_{DL_high}	
n257	26500 MHz – 29500 MHz	26500 MHz – 29500 MHz	TDD
n258	24250 MHz – 27500 MHz	24250 MHz – 27500 MHz	TDD
n259	39500 MHz – 43500 MHz	39500 MHz – 43500 MHz	TDD
n260	37000 MHz – 40000 MHz	37000 MHz – 40000 MHz	TDD
n261	27500 MHz – 28350 MHz	27500 MHz – 28350 MHz	TDD
n262	47200 MHz – 48200 MHz	47200 MHz – 48200 MHz	TDD

Supplementary UL & DL (SUL & SDL)

To improve UL coverage for high frequency scenarios, SUL can be configured. With SUL, the UE is configured with 2 ULs for one (1) DL of the same cell as depicted on Figure B.1-1 below:

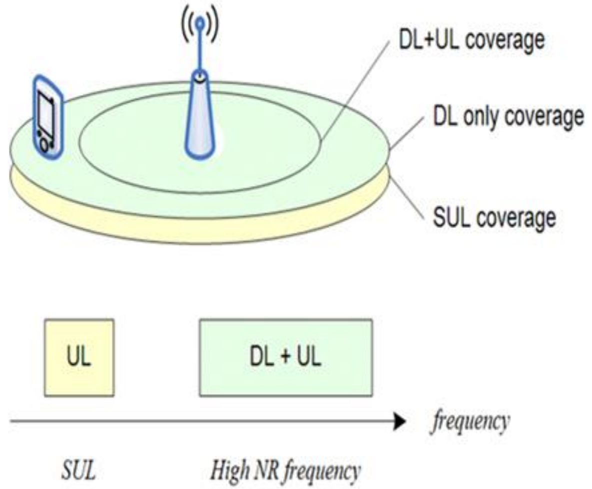


Figure B.1-1: Example of Supplementary Uplink

In case of FDD System, UL frequency is different from DL frequency. Thus, when Radio Resource restriction scenario is discussed, care should be taken by considering these variations e.g. Frequency used for both DL/ UL, UL only or DL only.

5G System introduces further flexibility in using Frequency Band, e.g. SUL (Supplementary UL) & SDL (Supplementary DL) can be used to replace the base frequency band, If the SUL &/or SDL band is restricted for a certain Network Slice (SST), some UEs may experience reduced coverage for the Network Slice.

Aspects related to carrier aggregation also needs to be considered similarly, because it is used to support QoS requirement by using different combination of DL bands & UL bands, e.g. using three DL bands together with one UL bands to boost downlink data rate.

Slicing 3

Network Slice Capability Exposure for Application Layer Enablement (NSCALE)

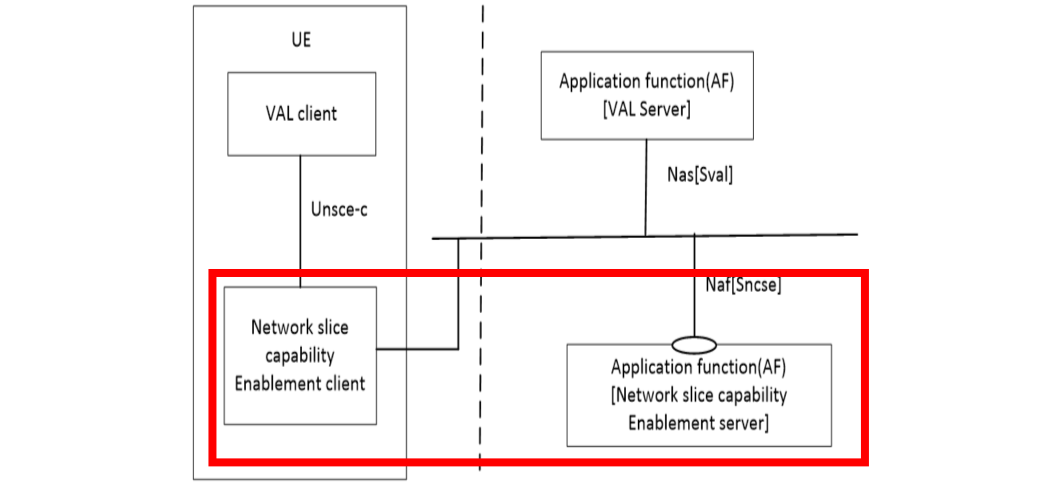


Figure Architecture for network slice capability enablement – Service based representation

1. **Key Issue #1: Network Slice Capability Management enhancements**
2. **Key Issue #2: Application Layer Exposed Network Slice Lifecycle Management**
3. **Key Issue #3: Discovery & Registration aspects for Management Service Exposure**
4. **Key Issue #4: Network Slice Fault Management Capability**
5. **Key Issue #5: Communication Service Management Exposure**
6. **Key Issue #6: Application Layer QoS verification Capability Enablement**
7. **Key Issue #7: Network Slice related Performance and Analytics Exposure**
8. **Key Issue #8: Support for Requirements Translation**
9. **Key Issue #9: Support for Trust Enablement**
10. **Key Issue #10: Support for Managing Trusted 3rd-Party owned Application(s)**
11. **Key Issue #11: Dynamic Slice SLA alignment**
12. **Key issue 12: Network Slice Capability Exposure in the Edge Data Network**
13. **Key issue 13: Delivery of the existing Network Slice Information to the Trusted 3rd-Party**
14. **Key issue 14: Network Slice creation to the 3rd-Party and UE**

Mapping of Solutions to Key Issues

Table : Mapping of Solutions to Key Issues

	Key issue 1	Key issue 2	Key issue 3	Key issue 4	Key issue 5	Key issue 6	Key issue 7	Key issue 8	Key issue 9	Key issue 10	Key issue 11
Solution 1		X									
Solution 2				X							
Solution 3								X			
Solution 4						X					
Solution 5							X				
Solution 6									X		
Solution 7			X								
Solution 8			X								
Solution 9										X	
Solution 10										X	
Solution 11					X						
…											

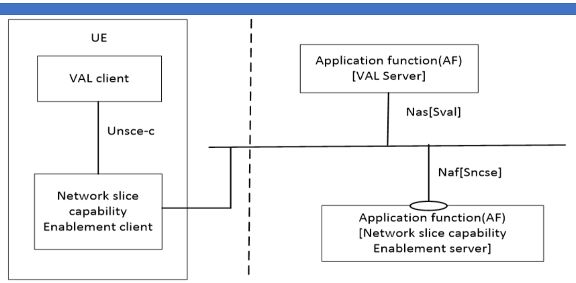
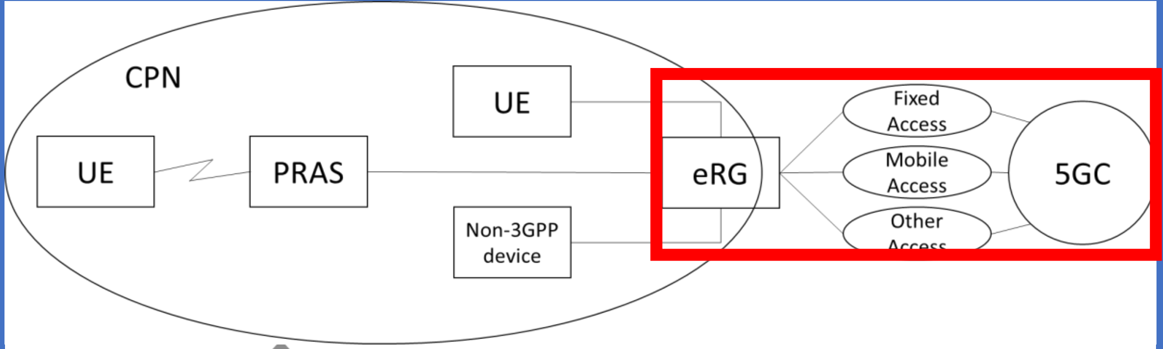


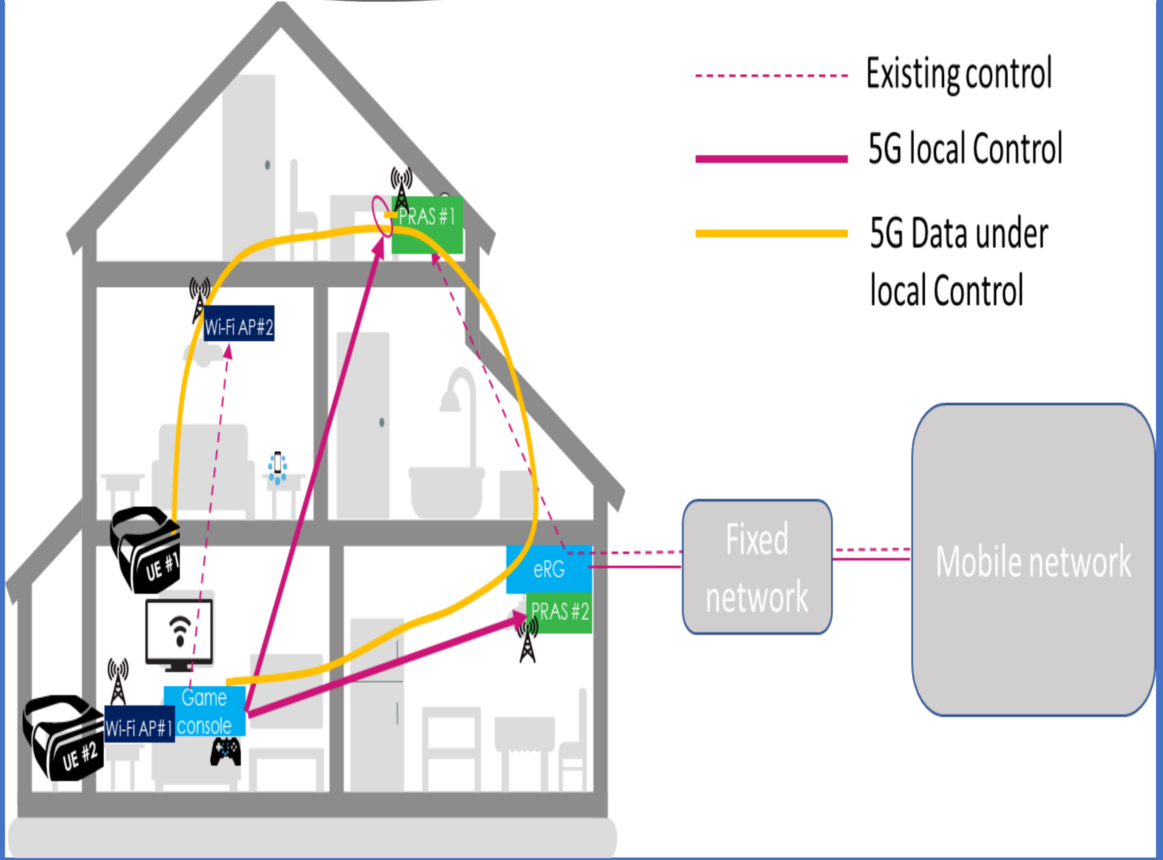
Figure Architecture for network slice capability enablement – Service based representation

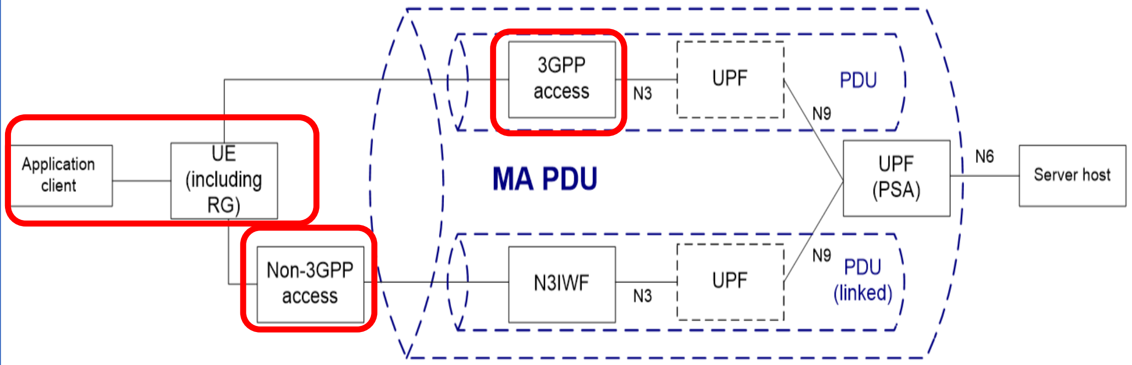
IoT/IIoT

	Mapping of IIoT Solutions to IIoT Key Issues (Kis)					
Nr Key Issues (KIs)	#1 Uplink Time Synchronization	#2 UE-UE TSC Communication	#3A Exposure of TSC Services: Exposure of Deterministic QoS	#3B Exposure of TSC Services Exposure of Time Synchronization	#4 Supporting the fully Distributed Configuration Model for TSN	#5 Use of Survival Time for Deterministic Applications in 5GS
1	X					
2		X				
3		X				
4		X				
5			X			
6			X			
7				X		
8				X		
9				X		
10		X				
11		X				
12		X				
13			X			
14			X			
15						X
16						x
17	X					
18	X			x		
19		X				
20		X				
21			X			
22			X			
23			X			
24		x				

Personal IoT Networks (PINs)







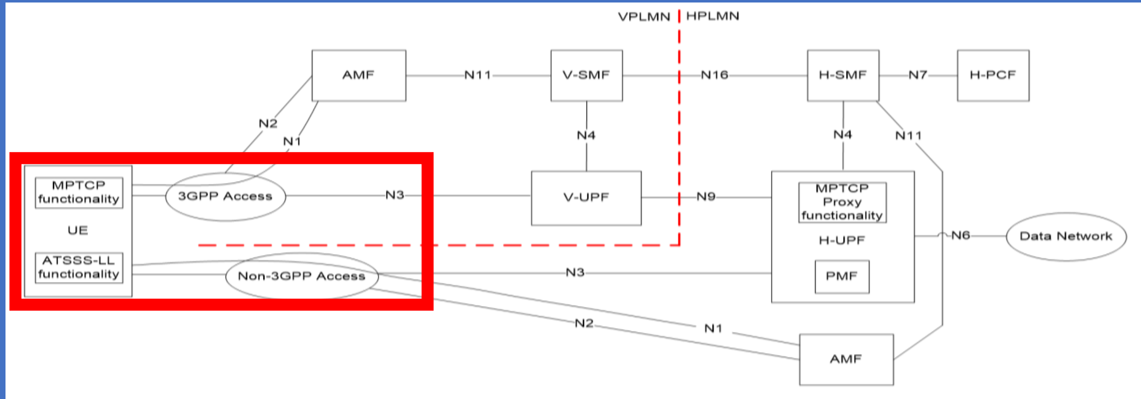


Figure : Roaming with Home-routed architecture for ATSSS support (UE registered to different PLMNs)

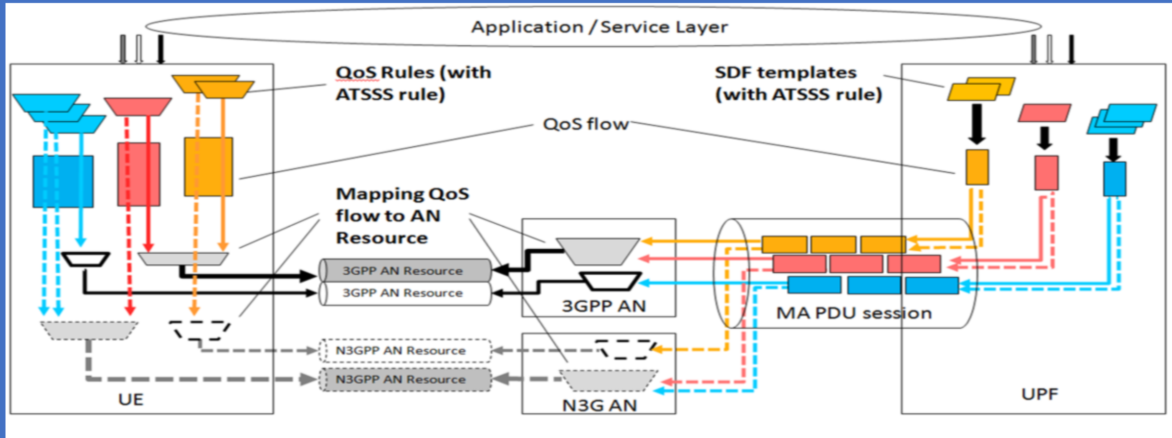


Figure : The traffic splitting based on the QoS rule (with ATSSS rule)

5G

Table 5.15.2.2-1: 5G Standardized Slice/Service Type (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.
V2X	4	Slice suitable for the handling of V2X services.
HMTC	5	Slice suitable for the handling of High-Performance Machine-Type Communications.

Attribute		Value
Availability		99.999
Device Velocity		0
UE density (per km^2)		1000
Mission critical support		Mission critical
	Mission-critical capability support	Inter-user prioritization
	Mission-critical service support	MCData
Slice quality of service	3GPP 5QI	83

Table 72 List of attributes needed for NEST for HMTC SST

Attribute		Value
Availability		99,9
Slice quality of service	3GPP 5QI	9
Supported device velocity		2
UE density		100000

Table 71 List of attributes needed for NEST for MIoT SST

3GPP RAN Rel-16 progress and Rel-17 potential work areas

July 18, 2019

https://www.3gpp.org/news-events/2058-ran-rel-16-progress-and-rel-17-potential-work-areas

Slide 7

Release 16 progressing towards completion

- 5G V2X
  - Targeting advanced use cases beyond LTE V2X
- Industrial IoT and URLLC enhancements
  - Adding 5G NR capabilities for full wired Ethernet replacement in factories: Time Sensitive networking, etc... with high reliability
- 5G NR operation in unlicensed bands
  - Includes both Licensed Assisted Access (LAA), as well as Standalone Unlicensed operation
- System improvements and enhancements
  - Positioning
  - MIMO enhancements
  - Power Consumption improvements

7

Wired to Wireless Link replacement

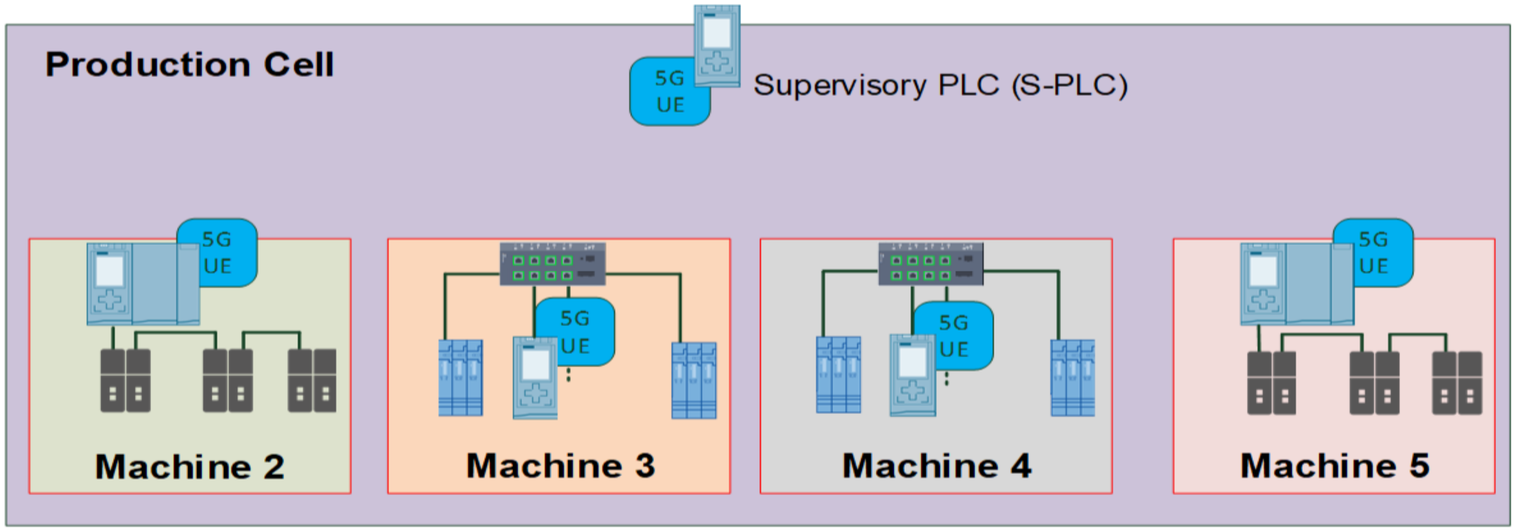


Figure : Example of four cooperating machines with wireless connections

Table : Service performance requirements for wired to wireless link replacement

Use case #	Characteristic parameter			Influence quantity					
	Communication service availability: target value [%]	Communication service reliability: mean time between failures	End-to-end latency: maximum	Data rate [Mbit/s]	Transfer interval	Survival time	UE speed	# of UEs	Service area (note 1)
1 (periodic traffic)	99.999 9 to 99.999 999	~ 10 years	< transfer interval value	50	≤ 1 ms	3 x transfer interval	stationary	2 to 5	100 m x 30 m x 10 m
1 (aperiodic traffic)	99.999 9 to 99.999 999	~ 10 years	< transfer interval value	25	≤ 1 ms (note 2)		stationary	2 to 5	100 m x 30 m x 10 m
2 (periodic traffic)	99.999 9 to 99.999 999	~ 10 years	< transfer interval value	250	≤ 1 ms	3 x transfer interval	stationary	2 to 5	100 m x 30 m x 10 m
2 (aperiodic traffic)	99.999 9 to 99.999 999	~ 10 years	< transfer interval value	500	≤ 1 ms (note 2)		stationary	2 to 5	100 m x 30 m x 10 m

NOTE 1: Length x width x height.
NOTE 2: Transfer interval also applies for scheduled aperiodic traffic

Stand-alone (SA) - NR-U (NR-Unlicensed) connected to 5GC.

This Scenario targets NPN

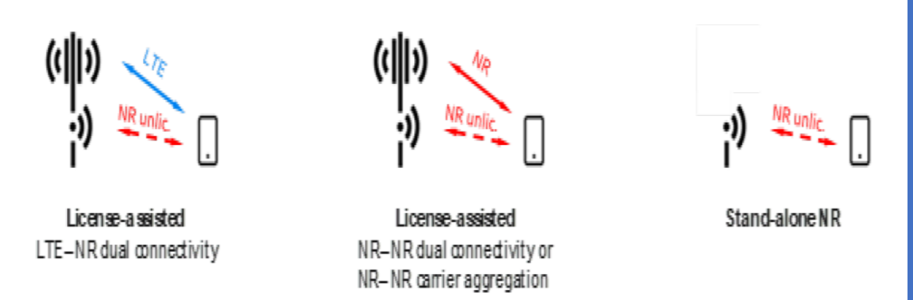


Fig. 3.10. License-assisted (left and middle) and stand-alone (right) operation of NR in unlicensed spectra.

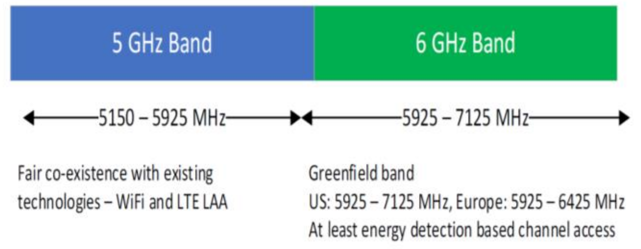


Fig. 3.9. Spectrum priorities for NR-U.

In 3GPP Rel. 16, NR was extended to support operation also in Un-licensed Spectra, with focus on the 5 GHz (5150-5925 GHz) & 6 GHz (5925 – 7150 GHz) bands (Figure 3.9).

- In contrast to LTE, which only supports License-Assisted-Access (LAA) operation in Un-licensed Spectrum,

- NR supports both LAA & Stand-alone (SA) Un-licensed Operation, see Figure 310.

In the case of LAA, a NR carrier in unlicensed spectrum is always operating jointly with a carrier in licensed spectrum, with the carrier in licensed spectrum used for initial access and mobility.

- The licensed carrier can be an NR carrier, but it can also be an LTE carrier. Dual connectivity is used in case of the licensed carrier using LTE. If the licensed carrier is using NR, either dual connectivity or carrier aggregation can be used between the licensed and unlicensed carrier.

In case of SA operation, an NR carrier in Un-licensed spectrum operates without support of a licensed carrier.

Thus, initial access and mobility are handled entirely using unlicensed spectra.

- The 5 GHz band is used by existing Technologies such as Wi-Fi & LTE-based LAA and it was a requirement, for the design of NR-U, or NR in Un-licensed spectrum,

Ref. 5G Americas, 3GPP Rel 16 & 17, & Beyond, Jan 2021: 34

The frequency ranges in which NR can operate according to this version of the specification are identified as described in Table 5.1-1.

Table 5.1-1: Definition of frequency ranges

Frequency range designation	Corresponding frequency range
FR1	410 MHz – 7125 MHz
FR2	24250 MHz – 52600 MHz

NR is designed to operate in the FR2 operating bands defined in Table 5.2-1.

Table 5.2-1: NR operating bands in FR2

Operating Band	Uplink (UL) operating band BS receive UE transmit	Downlink (DL) operating band BS transmit UE receive	Duplex Mode
	F_{UL_low} – F_{UL_high}	F_{DL_low} – F_{DL_high}	
n257	26500 MHz – 29500 MHz	26500 MHz – 29500 MHz	TDD
n258	24250 MHz – 27500 MHz	24250 MHz – 27500 MHz	TDD
n259	39500 MHz – 43500 MHz	39500 MHz – 43500 MHz	TDD
n260	37000 MHz – 40000 MHz	37000 MHz – 40000 MHz	TDD
n261	27500 MHz – 28350 MHz	27500 MHz – 28350 MHz	TDD
n262	47200 MHz – 48200 MHz	47200 MHz – 48200 MHz	TDD

Supplementary UL & DL (SUL & SDL)

To improve UL coverage for high frequency scenarios, SUL can be configured. With SUL, the UE is configured with 2 ULs for one (1) DL of the same cell as depicted on Figure B.1-1 below:

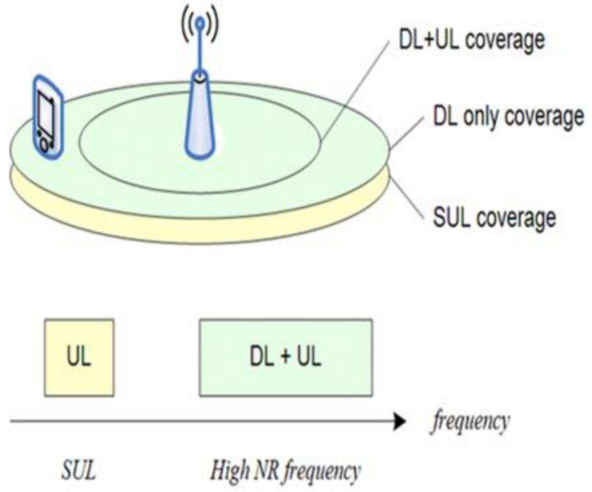


Figure B.1-1: Example of Supplementary Uplink

In case of FDD System, UL frequency is different from DL frequency. Thus, when Radio Resource restriction scenario is discussed, care should be taken by considering these variations e.g. Frequency used for both DL/ UL, UL only or DL only.

5G System introduces further flexibility in using Frequency Band, e.g. SUL (Supplementary UL) & SDL (Supplementary DL) can be used to replace the base frequency band, If the SUL &/or SDL band is restricted for a certain Network Slice (SST), some UEs may experience reduced coverage for the Network Slice.

Aspects related to carrier aggregation also needs to be considered similarly, because it is used to support QoS requirement by using different combination of DL bands & UL bands, e.g. using three DL bands together with one UL bands to boost downlink data rate.

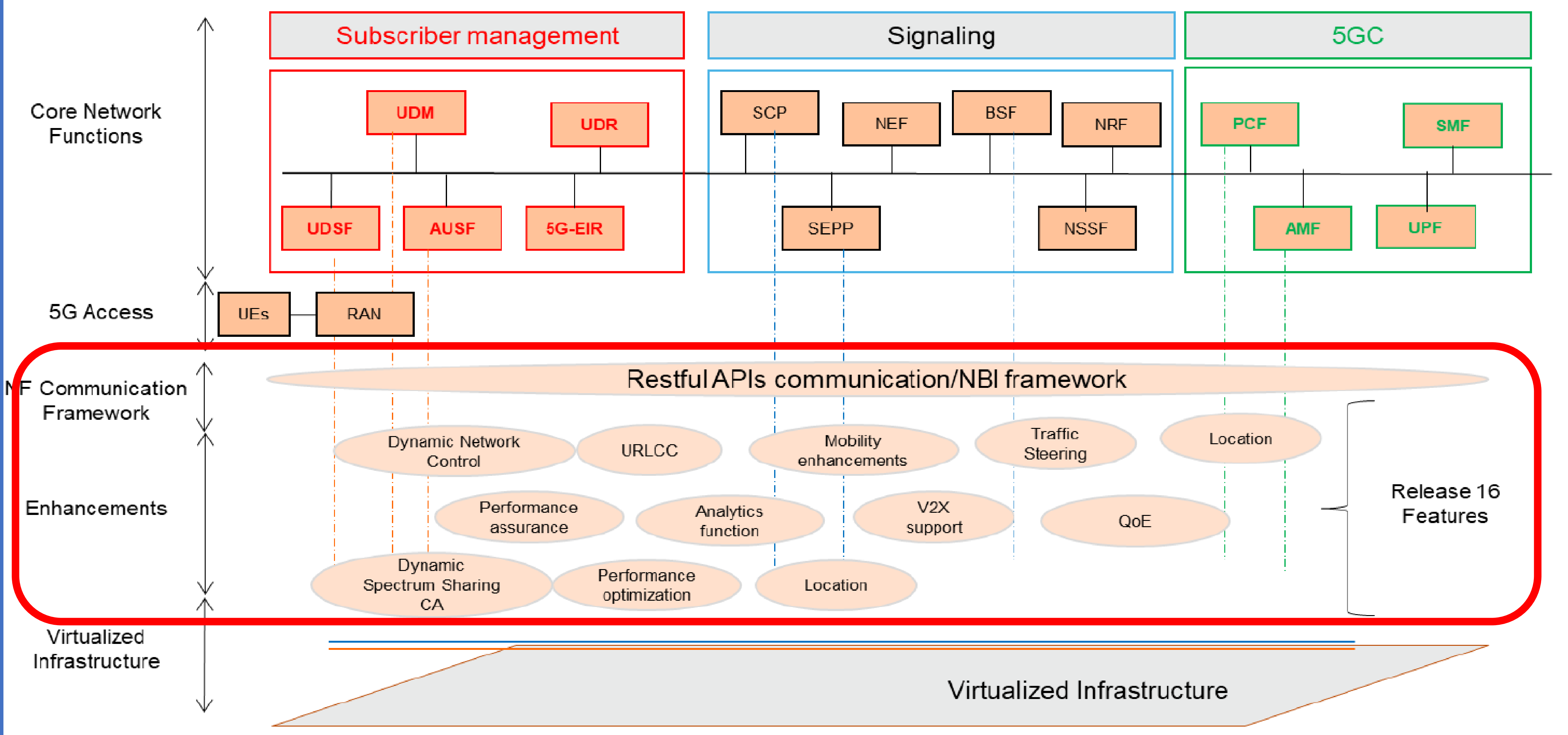


Figure 2-6: Release 16 5G features and enhancements supporting verticals

Redundant User Plane (UP) Paths based on Dual Connectivity

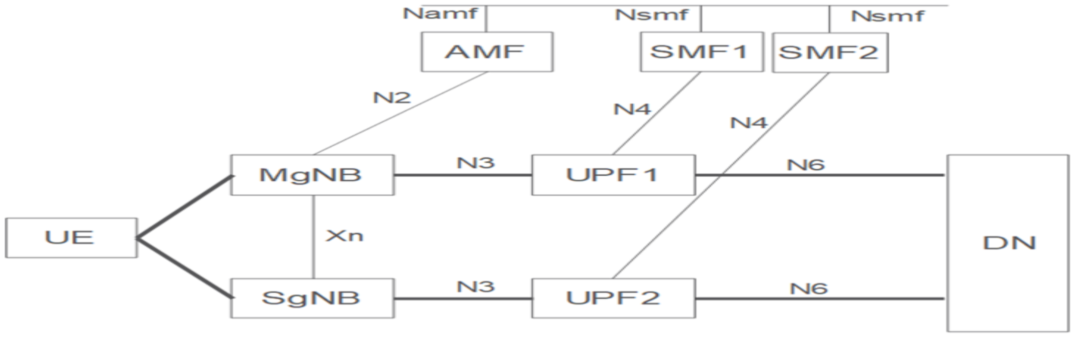


Figure Solution architecture

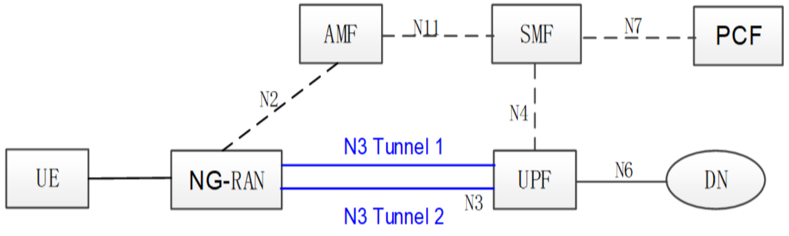


Figure Redundant transmission with two N3 tunnels between the UPF and a single NG-RAN node

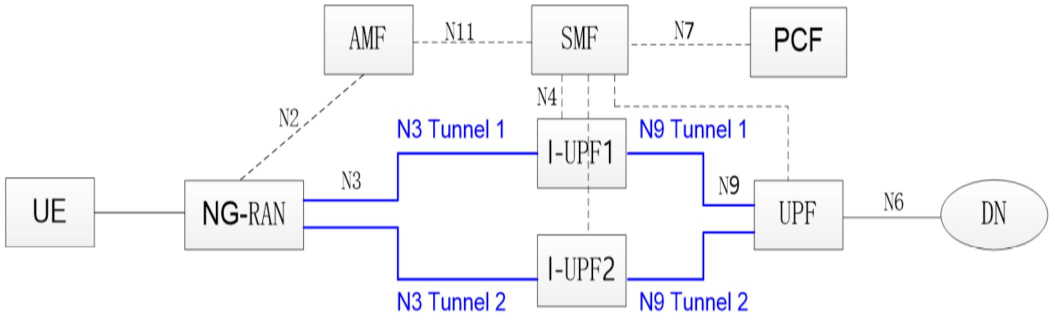


Figure Two N3 and N9 tunnels between NG-RAN and UPF for redundant transmission

Static approach:

This applies to both IP and Ethernet PDU sessions. The solution is illustrated in the Figure below:

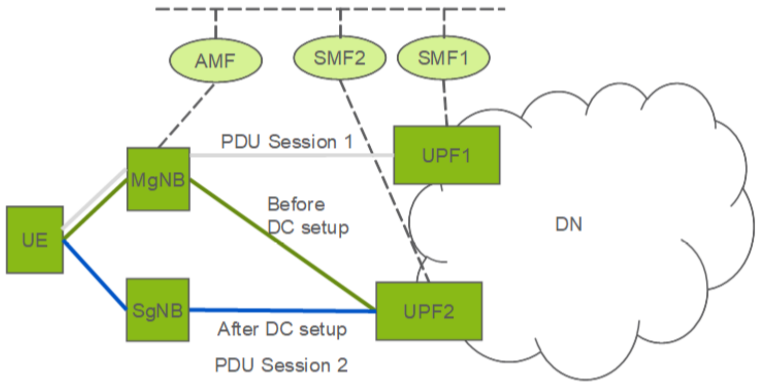


Figure 6.1.1-3: Static UPF selection

Dynamic approach:

This applies to Ethernet PDU Sessions. The solution is illustrated in the Figure below:

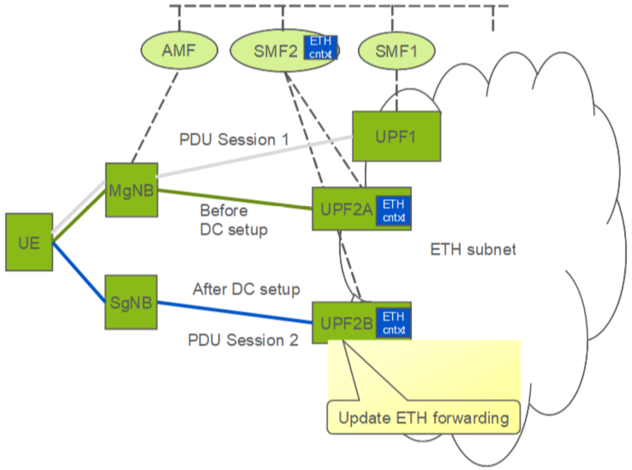
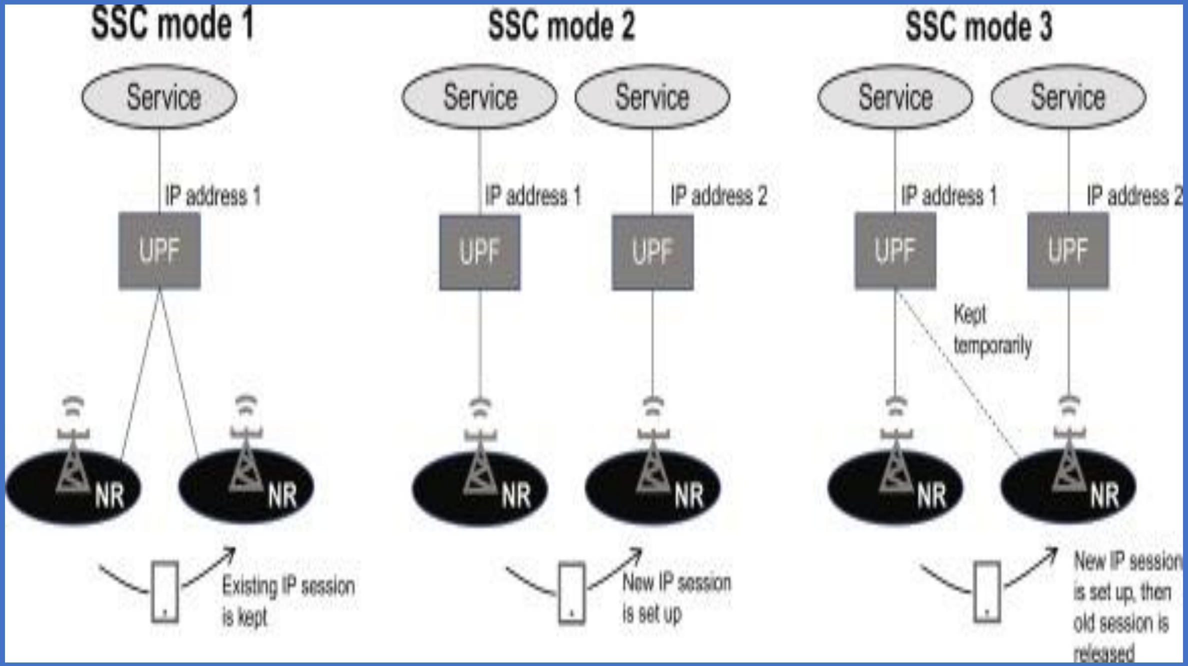


Figure Dynamic UPF Selection: anchor change after DC setup for Ethernet PDU Sessions



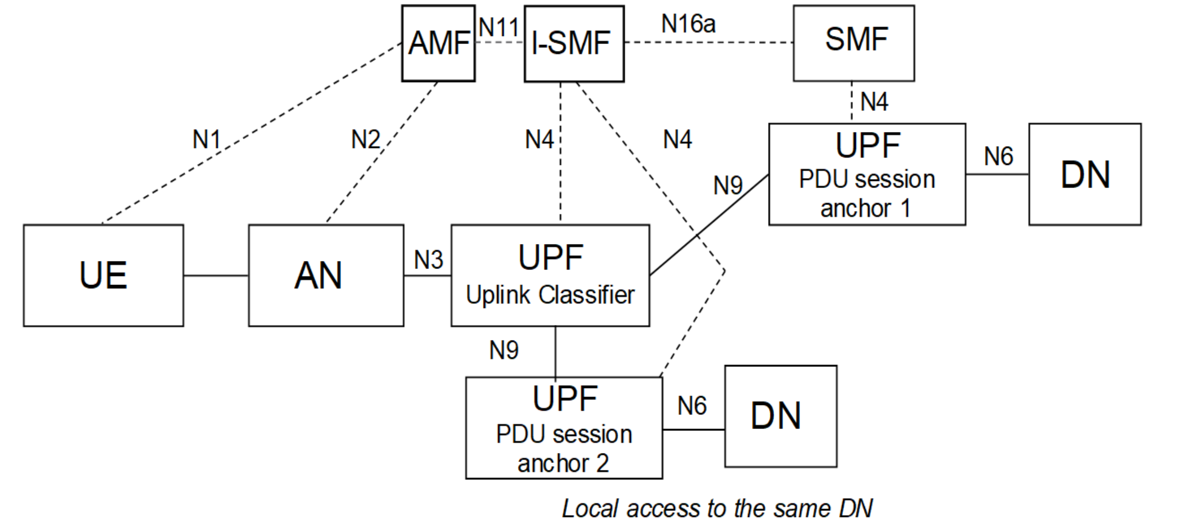


Figure User plane Architecture for the Uplink Classifier controlled by I-SMF

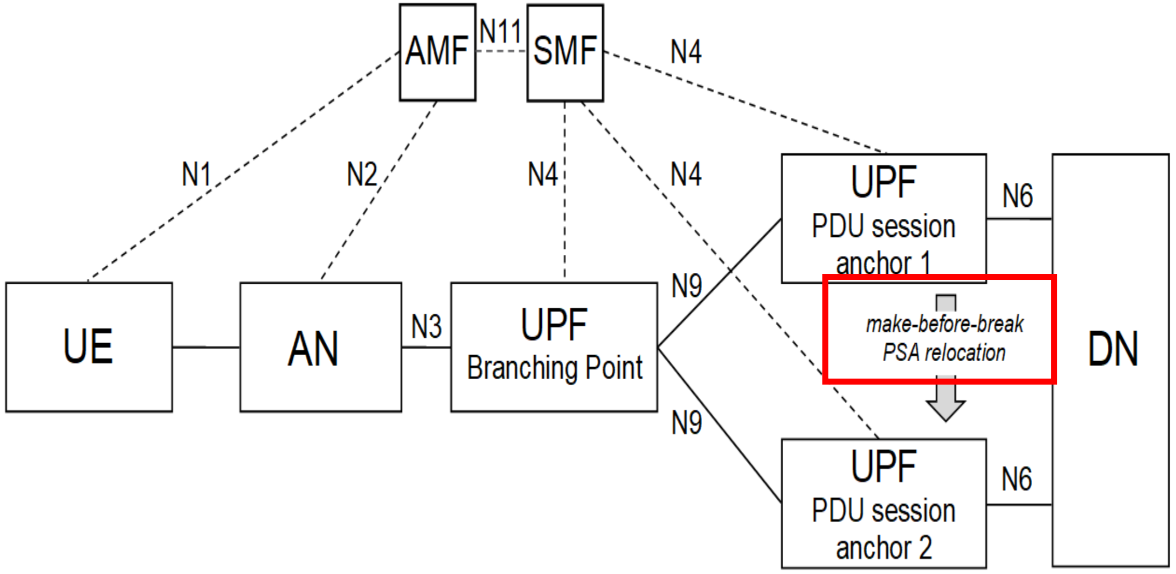


Figure Multi-homed PDU Session: service continuity case

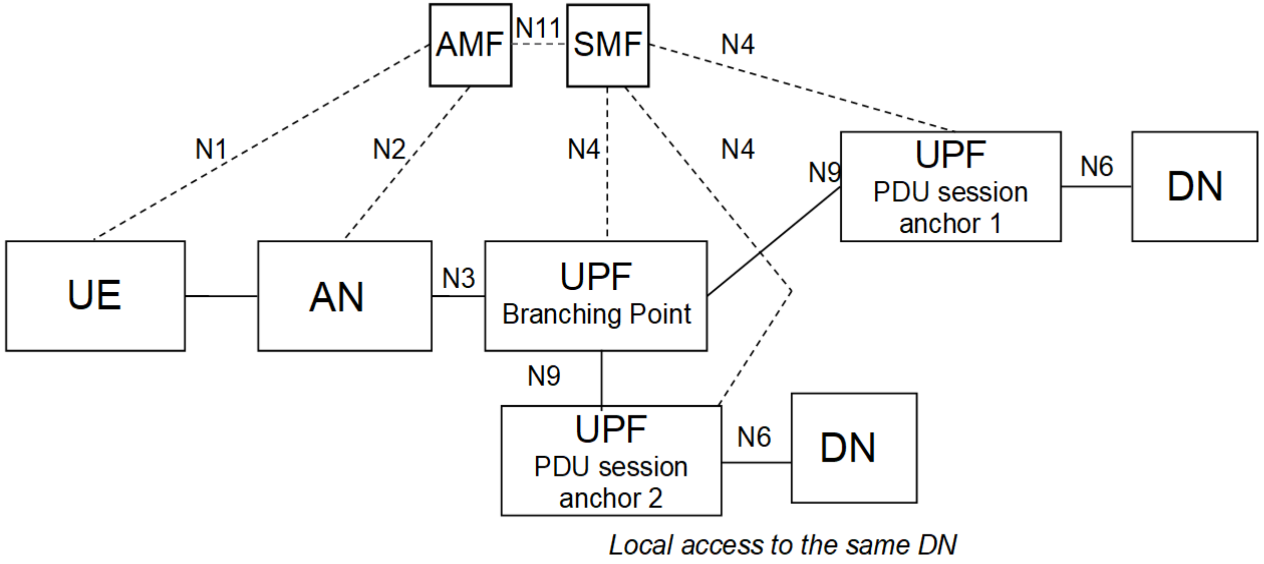


Figure Multi-homed PDU Session: local access to same DN

LTE/EPC QoS VS 5G QoS - 1

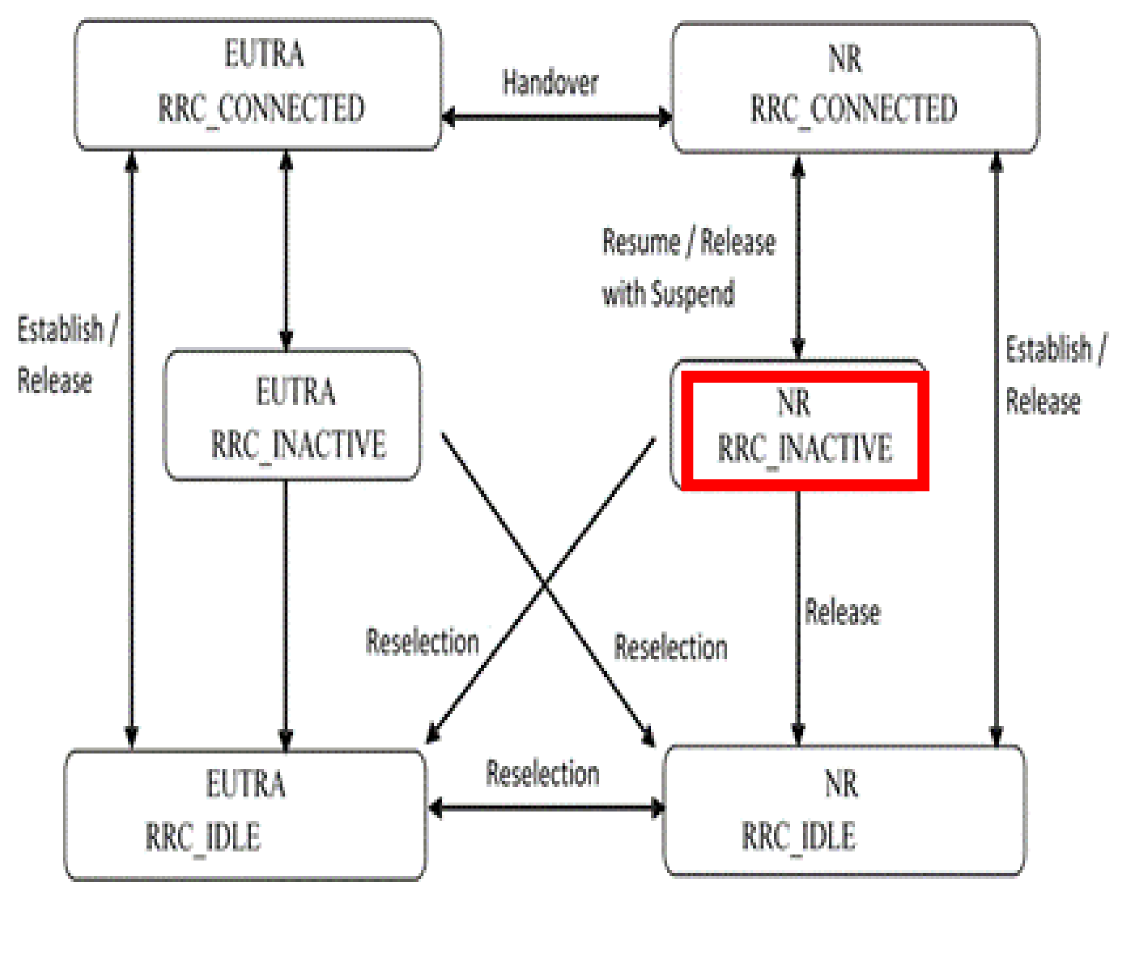


Figure : UE state machine and state transitions between NR/5GC, E-UTRA/EPC and E-UTRA/5GC

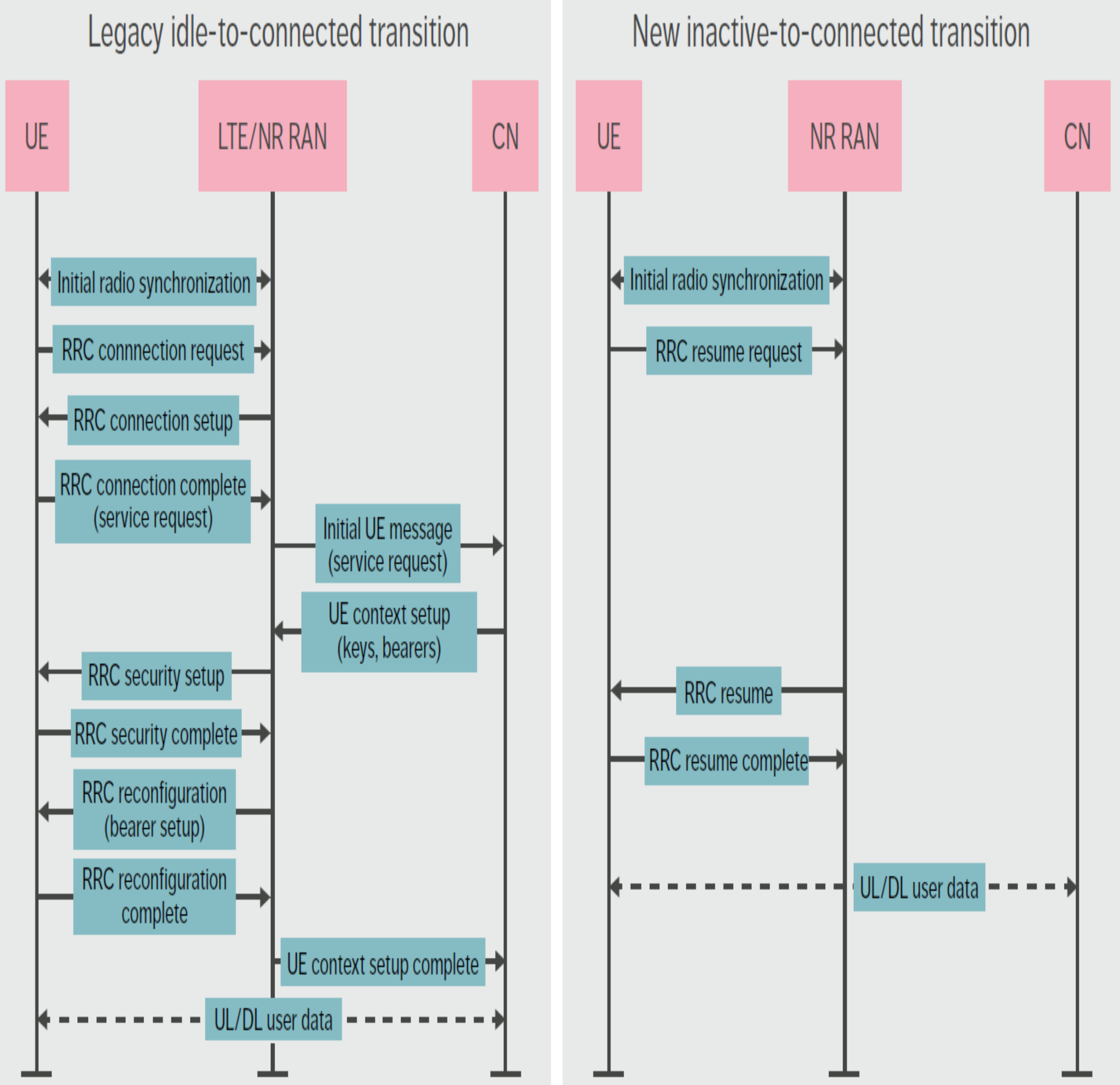


Figure 2 Comparison of Signalling involved in Legacy Idle-to-Connected transition (Left) versus Inactive-to-Connected Transition (Right)

IIoT

Table : Periodic deterministic communication service performance requirements

Characteristic parameter				Influence quantity						
Communication service availability: target value (note 1)	**Communication service reliability: mean time between failures**	**End-to-end latency: maximum (note 2)** (note 12a)	**Service bit rate: user experienced data rate** (note 12a)	**Message size [byte]** (note 12a)	**Transfer interval: target value** (note 12a)	**Survival time** (note 12a)	**UE speed** (note 13)	**# of UEs**	**Service area (note 3)**	**Remarks**
99.999 % to 99.999 99 %	~ 10 years	< transfer interval value	–	50	500 µs	500 µs	≤ 75 km/h	≤ 20	50 m x 10 m x 10 m	Motion control (A.2.2.1)
99.999 9 % to 99.999 999 %	~ 10 years	< transfer interval value	–	40	1 ms	1 ms	≤ 75 km/h	≤ 50	50 m x 10 m x 10 m	Motion control (A.2.2.1)
99.999 9 % to 99.999 999 %	~ 10 years	< transfer interval value	–	20	2 ms	2 ms	≤ 75 km/h	≤ 100	50 m x 10 m x 10 m	Motion control (A.2.2.1)
99.999 9 %	–	< 5 ms	1 kbit/s (steady state) 1.5 Mbit/s (fault case)	< 1,500	< 60 s (steady state) ≥ 1 ms (fault case)	transfer interval	stationary	20	30 km x 20 km	Electrical Distribution – Distributed automated switching for isolation and service restoration (A.4.4); (note 5)
99.999 9 % to 99.999 999 %	~ 10 years	< transfer interval value		1 k	≤ 10 ms	10 ms	-	5 to 10	100 m x 30 m x 10 m	Control-to-control in motion control (A.2.2.2); (note 9)
99.999 9 % to 99.999 999 %	~ 10 years	< transfer interval value (note 5)	50 Mbit/s		≤ 1 ms	3 x transfer interval	stationary	2 to 5	100 m x 30 m x 10 m	Wired-2-wireless 100 Mbit/s link replacement (A.2.2.4)
99.999 9 % to 99.999 999 %	~ 10 years	< transfer interval value (note 5)	250 Mbit/s		≤ 1 ms	3 x transfer interval	stationary	2 to 5	100 m x 30 m x 10 m	Wired-2-wireless 1 Gbit/s link replacement (A.2.2.4)
99.999 9 % to 99.999 999 %	~ 10 years	< transfer interval value		1 k	≤ 50 ms	50 ms	-	5 to 10	1,000 m x 30 m x 10 m	Control-to-control in motion control (A.2.2.2); (note 9)
> 99.999 9 %	~ 10 years	< transfer interval value	–	40 to 250	1 ms to 50 ms (note 6) (note 7)	transfer interval value	≤ 50 km/h	≤ 2,000	≤ 1 km²	Mobile robots (A.2.2.3)
99.999 9 % to 99.999 999 %	~ 1 month	< transfer interval value	–	40 to 250	4 ms to 8 ms (note 7)	transfer interval value	< 8 km/h (linear movement)	TBD	50 m x 10 m x 4 m	Mobile control panels – remote control of e.g. assembly robots, milling machines (A.2.4.1); (note 9)

Communica-tion service availability: target value (note 1)	Communication service reliability: mean time between failures	End-to-end latency: maximum (note 2) (note 12a)	Service bit rate: user experienced data rate (note 12a)	Message size [byte] (note 12a)	Transfer interval: target value (note 12a)	Survival time (note 12a)	UE speed (note 13)	# of UEs	Service area (note 3)	Remarks
99.999 999 %	1 day	< 8 ms (note 14)	250 kbit/s	40 to 250	8 ms	16 ms	quasi-static; up to 10 km/h	2 or more	30 m x 30 m	Mobile Operation Panel: Emergency stop (connectivity availability) (A.2.4.1A)
99.999 99 %	1 day	< 10 ms (note 14)	< 1 Mbit/s	< 1024	10 ms	~10 ms	quasi-static; up to 10 km/h	2 or more	30 m x 30 m	Mobile Operation Panel: Safety data stream (A.2.4.1A)
99.999 999 %	1 day	10 ms to 100 ms (note 14)	10 kbit/s	10 to 100	10 ms to 100 ms	transfer interval	stationary	2 or more	100 m² to 2,000 m²	Mobile Operation Panel: Control to visualization (A.2.4.1A)
99.999 999 %	1 day	< 1 ms (note 14)	12 Mbit/s to 16 Mbit/s	10 to 100	1 ms	~ 1 ms	stationary	2 or more	100 m²	Mobile Operation Panel: Motion control (A.2.4.1A)
99.999 999 %	1 day	< 2 ms (note 14)	16 kbit/s (UL) 2 Mbit/s (DL)	50	2 ms	~ 2 ms	stationary	2 or more	100 m²	Mobile Operation Panel: Haptic feedback data stream (A.2.4.1A)
99.999 9 % to 99.999 999 %	~ 1 year	< transfer interval	–	40 to 250	< 12 ms (note 7)	12 ms	< 8 km/h (linear movement)	TBD	typically 40 m x 60 m; maximum 200 m x 300 m	Mobile control panels - remote control of e.g. mobile cranes, mobile pumps, fixed portal cranes (A.2.4.1); (note 9)
99.999 9 % to 99.999 999 %	≥ 1 year	< transfer interval value	–	20	≥ 10 ms (note 8)	0	typically stationary	typically 10 to 20	typically ≤ 100 m x 100 m x 50 m	Process automation – closed loop control (A.2.3.1)
99.999 %	TBD	~ 50 ms	–	~ 100	~ 50 ms	TBD	stationary	≤ 100,000	several km² up to 100,000 km²	Primary frequency control (A.4.2); (note 9)
99.999 %	TBD	~ 100 ms	–	~ 100	~ 200 ms	TBD	stationary	≤ 100,000	several km² up to 100,000 km²	Distributed Voltage Control (A.4.3) (note 9)

Characteristic parameter				Influence quantity						
Communication service availability: target value (note 1)	**Communication service reliability: mean time between failures**	**End-to-end latency: maximum (note 2)** (note 12a)	**Service bit rate: user experienced data rate** (note 12a)	**Message size [byte]** (note 12a)	**Transfer interval: target value** (note 12a)	**Survival time** (note 12a)	**UE speed** (note 13)	**# of UEs**	**Service area (note 3)**	**Remarks**
> 99.999 9 %	~ 1 year	< transfer interval value	–	15 k to 250 k	10 ms to 100 ms (note 7)	transfer interval value	≤ 50 km/h	≤ 2,000	≤ 1 km^2	Mobile robots – video-operated remote control (A.2.2.3)
> 99.999 9 %	~ 1 year	< transfer interval value	–	40 to 250	40 ms to 500 ms (note 7)	transfer interval value	≤ 50 km/h	≤ 2,000	≤ 1 km^2	Mobile robots (A.2.2.3)
99.99 %	≥ 1 week	< transfer interval value	–	20 to 255	100 ms to 60 s (note 7)	≥ 3 x transfer interval value	typically stationary	≤ 10,000 to 100,000	≤ 10 km x 10 km x 50 m	Plant asset management (A.2.3.3)
>99.999 999 %	> 10 years	< 2 ms	2 Mbit/s to 16 Mbit/s	250 to 2,000	1 ms	transfer interval value	stationary	1	< 100 m^2	Robotic Aided Surgery (A.6.2)
>99.999 9 %	> 1 year	< 20 ms	2 Mbit/s to 16 Mbit/s	250 to 2,000	1 ms	transfer interval value	stationary	2 per 1,000 km^2	< 400 km (note 12)	Robotic Aided Surgery (A.6.2)
>99.999 %	>> 1 month (< 1 year)	< 20 ms	2 Mbit/s to 16 Mbit/s	80	1 ms	transfer interval value	stationary	20 per 100 km^2	< 50 km (note 12)	Robotic Aided Diagnosis (A.6.3)
99.999 9 % to 99.999 999 %	~ 10 years	< 0.5 x transfer interval	2.5 Mbit/s	250 500 with localisation information	> 5 ms > 2.5 ms > 1.7 ms (note 10)	0 transfer interval 2 x transfer interval (note 10)	≤ 6 km/h (linear movement)	2 to 8	10 m x 10 m x 5 m; 50 m x 5 m x 5 m (note 11)	Cooperative carrying – fragile work pieces; (ProSe communication) (A.2.2.5)
99.999 9 % to 99.999 999 %	~ 10 years	< 0.5 x transfer interval	2.5 Mbit/s	250 500 with localisation information	> 5 ms > 2.5 ms > 1.7 ms (note 10)	0 transfer interval 2 x transfer interval (note 10)	≤ 12 km/h (linear movement)	2 to 8	10 m x 10 m x 5 m; 50 m x 5 m x 5 m (note 11)	Cooperative carrying – elastic work pieces; (ProSe communication) (A.2.2.5)

Table : Communication service performance requirements for industrial wireless sensors

Characteristic parameter						Influence quantity					
Communica-tion service availability: target value	**Communication service reliability: mean time between failure**	**End-to-end latency** (note 6)	**Transfer interval (note 1)** (note 7)	**Service bit rate: user experienced data rate (note 2)** (note 7)	**Battery lifetime [year] (note 3)**	**Message Size [byte]** (note 7)	**Survival time** (note 7)	**UE speed**	**UE density [UE / m²]**	**Range [m] (note 4)**	**Remarks**
99.99 %	≥ 1 week	< 100 ms	100 ms to 60 s	≤ 1 Mbit/s	≥ 5	20 (note 5)	3 x transfer interval	stationary	Up to 1	< 500	Process monitoring, e.g. temperature sensor (A.2.3.2)
99.99 %	≥ 1 week	< 100 ms	≤ 1 s	≤ 200 kbit/s	≥ 5	25 k	3 x transfer interval	stationary	Up to 0.05	< 500	Asset monitoring, e.g. vibration sensor (A.2.3.2)
99.99 %	≥ 1 week	< 100 ms	≤ 1 s	≤ 2 Mbit/s	≥ 5	250 k	3 x transfer interval	stationary	Up to 0.05	< 500	Asset monitoring, e.g. thermal camera (A.2.3.2)

NOTE 1: The transfer interval deviates around its target value by < ± 25 %.
NOTE 2: The traffic is predominantly mobile originated.
NOTE 3: Industrial sensors can use a wide variety of batteries depending on the use case, but in general they are highly constrained in terms of battery size.
NOTE 4: Distance between the gNB and the UE.
NOTE 5: The application-level messages in this use case are typically transferred over Ethernet. For small messages, the minimum Ethernet frame size of 64 bytes applies and dictates the minimum size of the PDU sent over the air interface.
NOTE 6: It applies to both UL and DL unless stated otherwise.
NOTE 7: It applies to UL.

Table : Aperiodic deterministic communication service performance requirements

Characteristic parameter (KPI)				Influence quantity					
Communication service availability	**Communication service reliability: mean time between failures**	**Max Allowed End-to-end latency (note 1)** (note 5)	**Service bit rate: user-experienced data rate** (note 5)	**Message size [byte]** (note 5)	**Survival time**	**UE speed** (note 6)	**# of UEs**	**Service Area (note 3)**	**Remarks**
> 99.999 9 %	~ 1 week	10 ms	UL: > 10 Mbit/s	–	–	≤ 50 km/h	≤ 2,000	≤ 1 km^2	Mobile robots – video streaming (A.2.2.3)
99.999 9 % to 99.999 999 %	~ 1 month	< 30 ms	> 5 Mbit/s	–	–	< 8 km/h (linear movement)	TBD	TBD	Mobile control panels - parallel data transmission (A.2.4.1)
99.999 999 %	1 day	<8 ms (note 8)	250 kbit/s	40 to 250	16 ms	quasi-static; up to 10 km/h	2 or more	30 m x 30 m	Mobile Operation Panel: Emergency stop (emergency stop events) (A.2.4.1A)
99.999 9 %	–	< 50 ms	0.59 kbit/s 28 kbit/s	< 100	–	stationary	10 km^{-2} to 100 km^{-2}	TBD	Smart grid millisecond level precise load control (A.4.5)
> 99.9 %	~ 1 month	< 10 ms	–	–	–	< 8 km/h (linear movement)	≥ 3	20 m x 20 m x 4 m	Augmented reality; bi-directional transmission to image processing server (A.2.4.2)
99.999 9 % to 99.999 999 %	~ 10 years	< 1 ms (note 4)	25 Mbit/s	–	–	stationary	2 to 5	100 m x 30 m x 10 m	Wired-2-wireless 100 Mbit/s link replacement (A.2.2.4)
99.999 9 % to 99.999 999 %	~ 10 years	< 1 ms (note 4)	500 Mbit/s	–	–	stationary	2 to 5	100 m x 30 m x 10 m	Wired-2-wireless 1 Gbit/s link replacement (A.2.2.4)
> 99.9 %	–	DL: < 10 ms UL:<1 s (rural)	DL: > 100 kbit/s UL: > 5 Gbit/s (note 9)	–	–	stationary	> 100		Distributed energy storage; energy storage station video (A.4.6)
> 99.99 %	–	< 100 ms (note 10);	DL:<1 Mbit/s	–	–	–	–	–	Advanced metering (A.4.7)
> 99.999 %	–	20 ms	–	< 100 byte	–	–	–	several km^2	Distributed automated switching for isolation and service restoration (A.4.4.1) (note 7)
> 99.999 9 %		< 3 ms	–	160 byte	–	–	–	–	Distributed Energy Resources (DERs) and micro-grids (A.4.9) (note 7)

Table : Clock synchronization service performance requirements for 5G System

User-specific clock synchronicity accuracy level	Number of devices in one communication group for clock synchronisation	5GS synchronicity budget requirement (note 1)	Service area	Scenario
1	up to 300 UEs	≤ 900 ns	≤ 100 m x 100 m	- Motion control (A.2.2.1) - Control-to-control communication for industrial controller (A.2.2.2)
2	up to 300 UEs	≤ 900 ns	≤ 1,000 m x 100 m	- Control-to-control communication for industrial controller (A.2.2.2)
3	up to 10 UEs	< 10 µs	≤ 2,500 m^2	- High data rate video streaming
3a	up to 100 UEs	< 1 µs	≤ 10 km^2	- AVPROD synchronisation and packet timing
4	up to 100 UEs	< 1 µs	< 20 km^2	- Smart Grid: synchronicity between PMUs
4a	up to 100 UEs	< 250 ns to 1 µs	< 20 km^2	Smart Grid: IEC 61850-9-2 Sampled Values
4b	up to 100 UEs	<10-20 µs	< 20 km^2	Smart Grid: IEC 61850-9-2 Sampled Values – Power system protection in digital substation
4c	54/km^2 (note 2) 78/km^2 (note 3)	< 10 µs	several km^2	Smart Grid: Intelligent Distributed Feeder Automation (A.4.4.3)
4d	up to 100 UEs	<1 ms	< 20 km^2	Smart Grid: IEC 61850-9-2 Sampled Values – Event reporting and Disturbance recording
5	up to 10 UEs	< 50 µs	400 km	- Telesurgery (A.6.2) and telediagnosis (A.6.3)

NOTE 1: The clock synchronicity requirement refers to the clock synchronicity budget for the 5G system, as described in Clause 5.6.1.

NOTE 2: When the distributed terminals are deployed along overhead line, about 54 terminals will be distributed along overhead lines in one square kilometre. The resulting power load density is 20 MW/km^2.

NOTE 3: When the distributed terminals are deployed in power distribution cabinets, there are about 78 terminals in one square kilometre. The resulting power load density is 20 MW/km^2, Table : Service performance requirements for mobile robots

Use case #	Characteristic parameter				Influence quantity							
	Communication service availability: target value [%]	Communication service reliability: mean time between failures	End-to-end latency: maximum	Service bitrate: user experienced data rate	Message size [byte]	Transfer interval: lower bound	Transfer interval: target value (note)	Transfer interval: upper bound	Survival time	UE speed	# of UEs	Service area
1	> 99.999 9	~ 10 years	< target transfer interval value	–	40 to 250	– < 25 % of target transfer interval value	1 ms to 50 ms	+ < 25 % of target transfer interval value	target transfer interval value	≤ 50 km/h	≤ 2,000	≤ 1 km^2
2	> 99.999 9	~ 1 year	< target transfer interval value	–	15 k to 250 k	– < 25 % of target transfer interval value	10 ms to 100 ms	+ < 25 % of target transfer interval value	target transfer interval value	≤ 50 km/h	≤ 2,000	≤ 1 km^2
3	> 99.999 9	~ 1 year	< target transfer interval value	–	40 to 250	– < 25 % of target transfer interval value	40 ms to 500 ms	+ < 25 % of target transfer interval value	target transfer interval value	≤ 50 km/h	≤ 2,000	≤ 1 km^2
4	> 99.999 9	~ 1 week	10 ms	> 10 Mbit/s	–	–		–	–	≤ 50 km/h	≤ 2,000	≤ 1 km^2

NOTE: The transfer interval is not so strictly periodic in these use cases. The transfer interval deviates around its target value within bounds. The mean of the transfer interval is close to the target value.

Table : Service performance requirements for augmented reality in human-machine interfaces

Use case #	Characteristic parameter			Influence quantity	
	Communication service availability: target value [%]	Communication service reliability: mean time between failures	End-to-end latency: maximum	UE speed	Service area (note)
1	> 99.9	~ 1 month	< 10 ms	< 8 km/h	20 m x 20 m x 4 m
NOTE: Length x width x height.					

Table : Key Performance for uninterrupted MTC service availability

Characteristic parameter (KPI)				Influence quantity				
Communication service availability: target value	Communication service reliability: mean time between failures	Max Allowed End-to-end latency (note 1; (note 2)	Service bit rate: user-experienced data rate (note 2)	Message size [byte]	Survival time	UE speed	# of UEs	Service Area
99.999 9 %	–	100 ms	< 1 kbit/s per DER	–	–	Stationary	–	–
NOTE 1: Unless otherwise specified, all communication includes 1 wireless link (UE to network node or network node to UE) rather than two wireless links (UE to UE). NOTE 2: It applies to both UL and DL unless stated otherwise.								

Use case 1 - Process automation: Dolly tracking (outdoor).

Use case 2 - Process automation: Asset tracking.

Use case 3 - Flexible modulare assembly area: Tool tracking in flexible, modular assembly areas in smart factories.

Use case 4 - Process automation: Sequence container (Intralogistics).

Use case 5 - Process automation: Palette tracking (e.g. in turbine construction).

Use case 6 - Flexible modulare assembly area: Tracking of workpiece (in- and outdoor) in assembly area and warehouse.

Use case 7 - Flexible modulare assembly area: Tool assignment (assign tool to vehicles in a production line, left/right) in flexible, modular assembly area in smart factories.

Use case 8 - Flexible modulare assembly area: Positioning of autonomous vehicles for monitoring purposes (vehicles in line, distance 1.5 meter).

Use case 9 - (Intra-)logistics: Asset tracking

Table : Low power high accuracy positioning use cases

Use Case #	Horizontal accuracy	Corresponding service level (22.261)	Positioning interval/ duty cycle	battery life time/ minimum operation time
1	10 m	Service Level 1	on request	24 months
2	2 m to 3 m	Service Level 2	< 4 seconds	> 6 months
3	< 1 m	Service Level 3	no indication	1 work shift - 8 hours (up to 3 days, 1 month for inventory purposes)
4	< 1 m	Service Level 3	1 second	6 - 8 years
5	< 1 m	Service Level 3	5 seconds - 15 minutes	18 months
6	< 1 m	Service Level 3	15 s to 30 s	6 - 12 months
7	30 cm	Service Level 5	250 ms	18 months
8	30 cm	Service Level 5	1 second	6 - 8 years (no strong limitation in battery size)
9	10 m	Service Level 1	20 minutes	12 years (@20mJ/position fix)

Table Performance requirements for Horizontal and Vertical positioning service levels

Positioning service level	Absolute(A) or Relative(R) positioning	Accuracy (95 % confidence level)		Positioning service availability	Positioning service latency	Coverage, environment of use and UE velocity		
		Horizontal Accuracy	Vertical Accuracy (note 1)			5G positioning service area	5G enhanced positioning service area (note 2)	
							Outdoor and tunnels	Indoor
1	A	10 m	3 m	95 %	1 s	Indoor - up to 30 km/h Outdoor (rural and urban) up to 250 km/h	NA	Indoor - up to 30 km/h
2	A	3 m	3 m	99 %	1 s	Outdoor (rural and urban) up to 500 km/h for trains and up to 250 km/h for other vehicles	Outdoor (dense urban) up to 60 km/h Along roads up to 250 km/h and along railways up to 500 km/h	Indoor - up to 30 km/h
3	A	1 m	2 m	99 %	1 s	Outdoor (rural and urban) up to 500 km/h for trains and up to 250 km/h for other vehicles	Outdoor (dense urban) up to 60 km/h Along roads up to 250 km/h and along railways up to 500 km/h	Indoor - up to 30 km/h
4	A	1 m	2 m	99,9 %	15 ms	NA	NA	Indoor - up to 30 km/h
5	A	0,3 m	2 m	99 %	1 s	Outdoor (rural) up to 250 km/h	Outdoor (dense urban) up to 60 km/h Along roads and along railways up to 250 km/h	Indoor - up to 30 km/h
6	A	0,3 m	2 m	99,9 %	10 ms	NA	Outdoor (dense urban) up to 60 km/h	Indoor - up to 30 km/h
7	R	0,2 m	0,2 m	99 %	1 s	Indoor and outdoor (rural, urban, dense urban) up to 30 km/h Relative positioning is between two UEs within 10 m of each other or between one UE and 5G positioning nodes within 10 m of each other (note 3)		

NOTE 1: The objective for the vertical positioning requirement is to determine the floor for indoor use cases and to distinguish between superposed tracks for road and rail use cases (e.g. bridges).

NOTE 2: Indoor includes location inside buildings such as offices, hospital, industrial buildings.

NOTE 3: 5G positioning nodes are infrastructure equipment deployed in the service area to enhance positioning capabilities (e.g. beacons deployed on the perimeter of a rendezvous area or on the side of a warehouse).

Table : Performance requirements for highly reliable machine type communication

Profile	Characteristic parameter					Influence quantity					
	Communication service availability: target value in %	Communication service reliability (Mean Time Between Failure)	End-to-end latency: maximum	Bit rate	Direction	Message Size [byte]	Transfer Interval	Survival Time	UE speed (km/h)	# of UEs connection	Service Area
Medical monitoring (note 2)	> 99,9999	<1 year (>> 1 month)	< 100 ms	< 1 Mbit/s	Uplink	~ 1000	50 ms	Transfer Interval	< 500	10/km^2 to 1000/km^2	Country wide including rural areas and deep indoor. (note 1)

NOTE 1: “deep indoor” term is meant to be places like e.g. elevators, building’s basement, underground parking lot, …
NOTE 2: These performance requirements aim energy-efficient transmissions performed using a device powered with a 3.3V battery of capacity < 1000 mAh that can last at least 1 month without recharging and whereby the peak current for transmit operations stays below 50 mA.

Table KPI Table for additional high data rate and low latency service

Use Cases	Characteristic parameter (KPI)			Influence quantity		
	Max allowed end-to-end latency	Service bit rate: user-experienced data rate	Reliability	# of UEs	UE Speed	Service Area (note 2)
Cloud/Edge/Split Rendering (note 1)	5 ms (i.e. UL+DL between UE and the interface to data network) (note 4)	0,1 to [1] Gbit/s supporting visual content (e.g. VR based or high definition video) with 4K, 8K resolution and up to120 frames per second content.	99,99 % in uplink and 99,9 % in downlink (note 4)	-	Stationary or Pedestrian	Countrywide
Gaming or Interactive Data Exchanging (note 3)	10ms (note 4)	0,1 to [1] Gbit/s supporting visual content (e.g. VR based or high definition video) with 4K, 8K resolution and up to120 frames per second content.	99,99 % (note 4)	≤ [10]	Stationary or Pedestrian	20 m x 10 m; in one vehicle (up to 120 km/h) and in one train (up to 500 km/h)
Consumption of VR content via tethered VR headset (note 6)	[5 to 10] ms (note 5)	0,1 to [10] Gbit/s (note 5)	[99,99 %]	-	Stationary or Pedestrian	–

NOTE 1: Unless otherwise specified, all communication via wireless link is between UEs and network node (UE to network node and/or network node to UE) rather than direct wireless links (UE to UE).
NOTE 2: Length x width (x height).
NOTE 3: Communication includes direct wireless links (UE to UE).
NOTE 4: Latency and reliability KPIs can vary based on specific use case/architecture, e.g. for cloud/edge/split rendering, and can be represented by a range of values.
NOTE 5: The decoding capability in the VR headset and the encoding/decoding complexity/time of the stream will set the required bit rate and latency over the direct wireless link between the tethered VR headset and its connected UE, bit rate from 100 Mbit/s to [10] Gbit/s and latency from 5 ms to 10 ms.
NOTE 6: The performance requirement is valid for the direct wireless link between the tethered VR headset and its connected UE.

Table KPI Table of split AI/ML inference between UE and Network Server/Application function

Uplink KPI					Downlink KPI				
Max allowed UL end-to-end latency	Experienced data rate	Payload size	Communication service availability	Reliability	Max allowed DL end-to-end latency	Experienced data rate	Payload size	Reliability	Remarks
2 ms	1.08 Gbit/s	0.27 MByte	99.999 %	99.9 %				99.999 %	Split AI/ML image recognition
100 ms	1.5 Mbit/s				100 ms	150 Mbit/s	1.5 MByte/ frame		Enhanced media recognition
	4.7 Mbit/s				12 ms	320 Mbit/s	40 kByte		Split control for robotics

NOTE 1: Communication service availability relates to the service interfaces, and reliability relates to a given system entity. One or more retransmissions of network layer packets can take place in order to satisfy the reliability requirement.

Table : KPI Table of Federated Learning between UE and Network Server/Application function

Max allowed DL or UL end-to-end latency	DL experienced data rate	UL experienced data rate	DL packet size	UL packet size	Communication service availability	Remarks
1s	1.0Gbit/s	1.0Gbit/s	132MByte	132MByte		Uncompressed Federated Learning for image recognition
1s	80.88Mbit/s	80.88Mbit/s	10Mbyte	10Mbyte	TBD	Compressed Federated Learning for image/video processing
1s	TBD	TBD	10MByte	10MByte		Data Transfer Disturbance in Multi-agent multi-device ML Operations

Table KPI Table of AI/ML model downloading

Max allowed DL end-to-end latency	Experienced data rate (DL)	Model size	Communication service availability	Reliability	User density	# of downloaded AI/ML models	Remarks
1s	1.1Gbit/s	138MByte	99.999 %	99.9% for data transmission of model weight factors; 99.999% for data transmission of model topology			AI/ML model distribution for image recognition
1s	640Mbit/s	80MByte	99.999 %				AI/ML model distribution for speech recognition
1s	512Mbit/s(see note 1)	64MByte				Parallel download of up to 50 AI/ML models	Real time media editing with on-board AI inference
1s		536MByte			up to 5000~ 10000/km2 in an urban area		AI model management as a Service
1s	22Mbit/s	2.4MByte	99.999 %				AI/ML based Automotive Networked Systems
1s		500MByte					Shared AI/ML model monitoring
3s	450Mbit/s	170MByte					Media quality enhancement

NOTE 1: 512Mbit/s concerns AI/ML models having a payload size below 64 MB. TBD for larger payload sizes.
NOTE 2: Communication service availability relates to the service interfaces, and reliability relates to a given system entity. One or more retransmissions of network layer packets can take place in order to satisfy the reliability requirement.

LTE/EPC QoS VS 5G QoS

LTE/EPC QoS VS 5G QoS

Reliability covers the communication-related aspects between two nodes (here: end nodes), while communication service availability addresses the communication-related aspects between two communication service interfaces. This might seem to be a small difference, but this difference can lead to situations, where reliability and communication service availability have different values.

Example: Traffic gets "stuck"   The related Scenario is depicted in Fig. below.

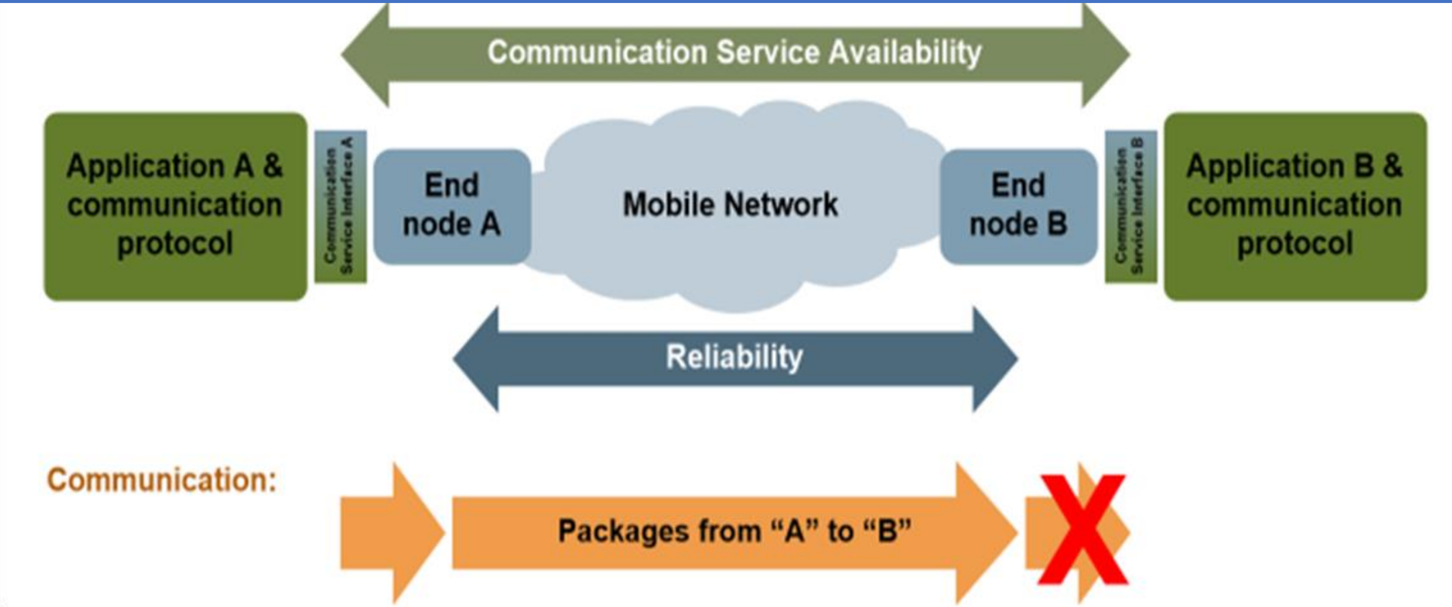


Fig.: Example in which Reliability and Communication Availability have different vaues. Packets are reliably transmitted from the Communication Service Interface A to the End Node B, but they are not exposed at the Communication Service Interface B.

Table: Example of Relationship between Reliability and Communication Service Availability when the Survival Time is equal to the Transfer Interval

Communication service availability	Reliability 1 - p
99.999 9 %	99.9 %
99.999 999 %	99.99 %
99.999 999 99 %	99.999 %
99.999 999 999 9 %	99.999 9 %
99.999 999 999 999 %	99.999 99 %

Table: Example of Relationship between Reliability and Communication Service Availability when the Survival Time is equal to the Transfer Interval

Communication service availability	Reliability 1 - p
99.999 9 %	99.9 %
99.999 999 %	99.99 %
99.999 999 99 %	99.999 %
99.999 999 999 9 %	99.999 9 %
99.999 999 999 999 %	99.999 99 %

Relation of Communication Service: Availability and Reliability

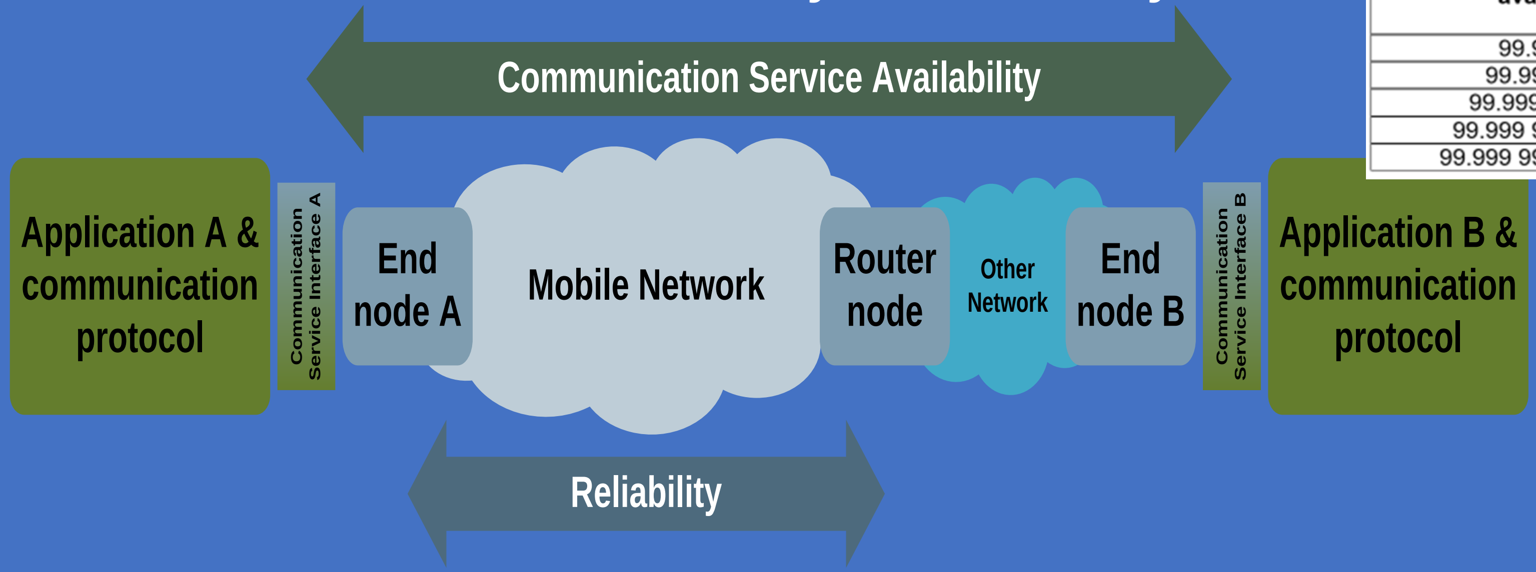


Figure C-4: Example in which communication Service Availability & Reliability have different values.

Packets are delivered over a daisy chain of a Mobile Network and another Network (e.g. IEEE 802.11n based).

Reliability is evaluated for the Mobile Network only,
Availability depends on the performance of both Networks.

Communication Service **Availability** - measured between the two (2) Communication Service Interfaces,

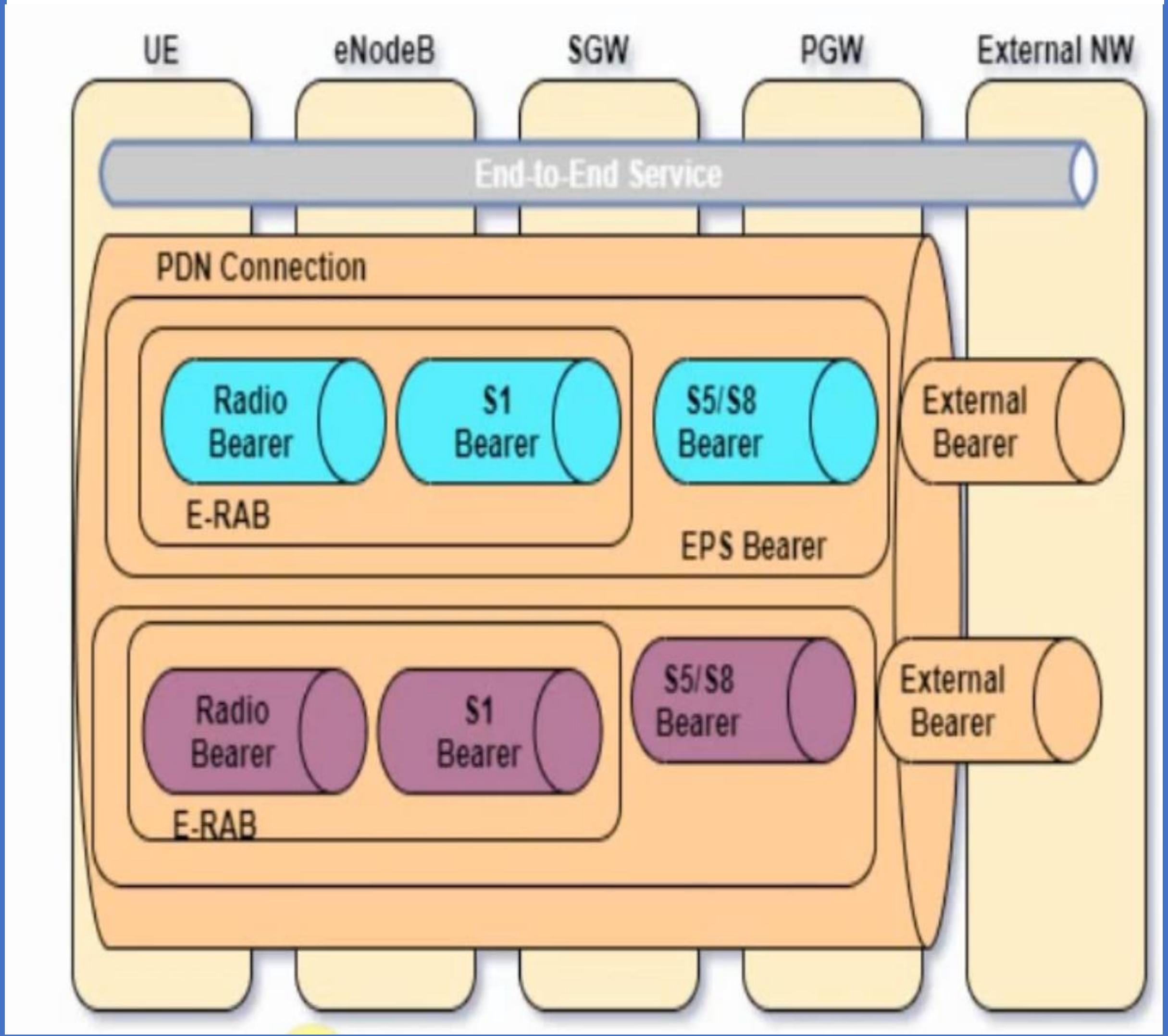
Reliability - measured between End Node A and the Router Node.

This has implications for, e.g. the maximum communication latency allowed for each network. In case the agreed end-to-end latency between the service interfaces is, for instance, 100 ms, and the 802.11n network has a latency of 30 ms, the maximum allowable latency for packages in the mobile network is 70 ms (NOTE). So, if the latency in the mobile network exceeds 70 ms, the communication service availability is 0%, despite the agreed QoS stipulating a larger end-to-end latency, i.e. 100ms.

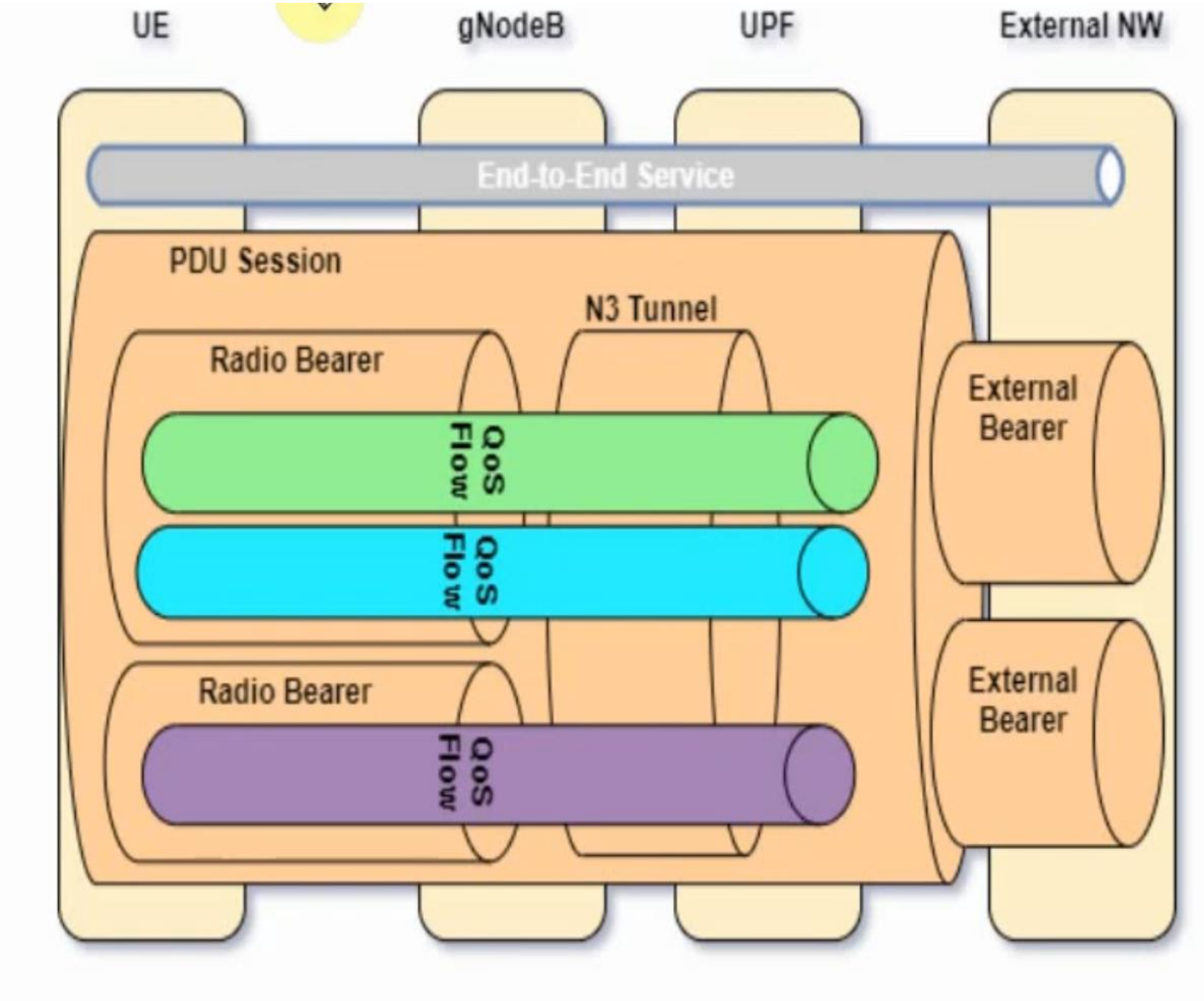
NOTE: The transit time through the router node is not considered here. It is assumed to be very small and much less than 100 ms.

5G QoS 4G vs 5G QoS

4G/LTE QoS



5G QoS

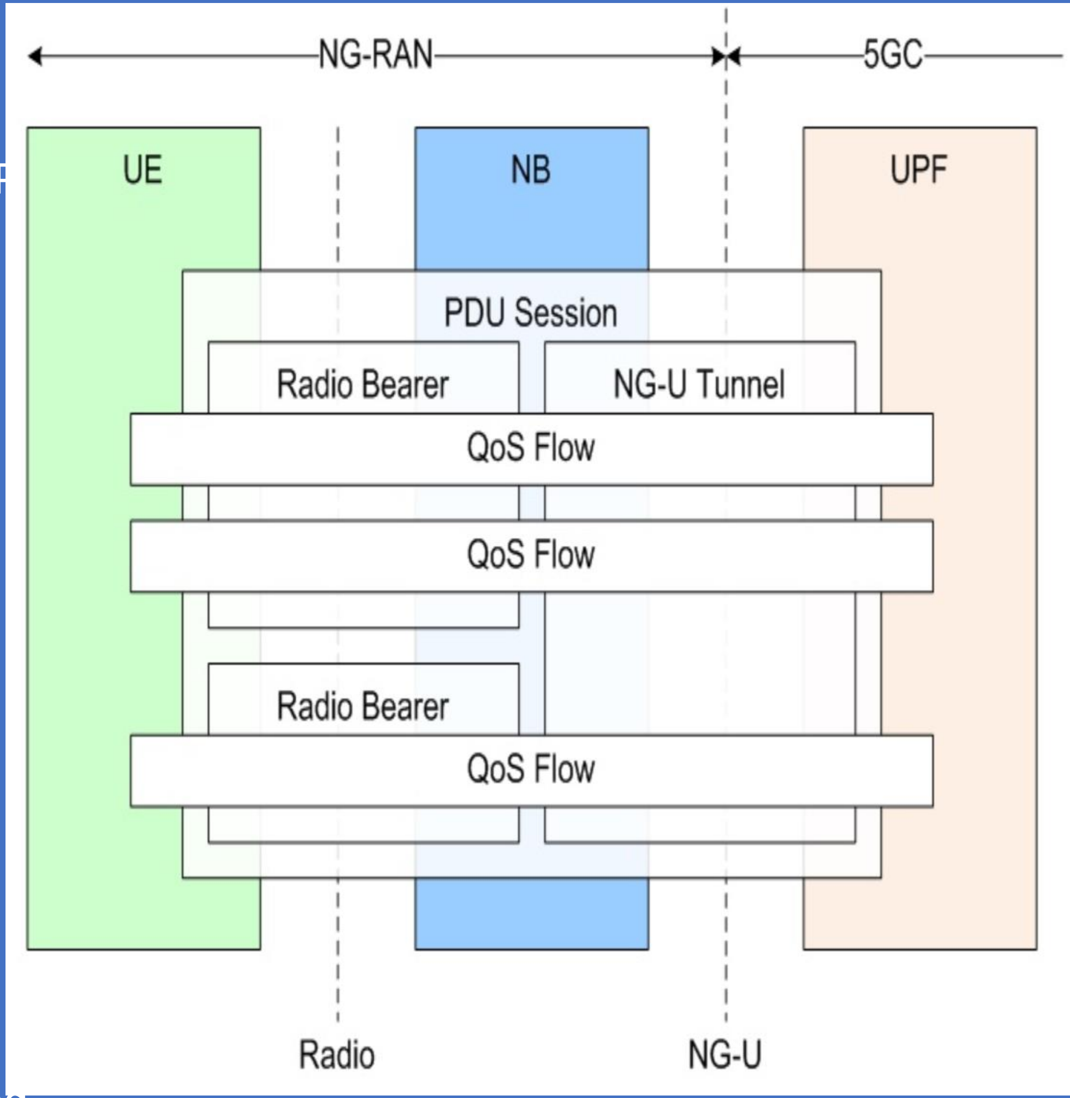


Ref. Telco Bytes Dec 2020

5G QoS 4G vs 5G QoS

5G NR network QoS architecture

Below You can see the 5G NR network QoS architecture (details in 3GPP 38.300)



For each QoS flow are assigned:

5G QoS Identifier (5QI);
An Allocation and Retention Priority (ARP);

For GBR QoS flow :
Guaranteed Flow Bit Rate (GFBR) for DL (downlink) and UL (uplink);
Maximum Flow Bit Rate (MFBR) for DL (downlink) and UL (uplink) ;
Maximum Packet Loss Rate for DL (downlink) and UL (uplink) ;

For Non-GBR QoS:
Reflective QoS Attribute (RQA);
Requirements for each services of the 5G NR network, (for each assigned 5QI) is strictly regulated by 3GPP TS 23.501 and are presented in the table below

The 5G QoS Model is based on QoS Flows.

The 5G QoS Model supports both QoS Flows that require Guaranteed flow Bit Rate (GBR QoS Flows) and QoS Flows that do not require Guaranteed flow Bit Rate (Non-GBR QoS Flows).

The 5G QoS Model also supports Reflective QoS

The QoS Flow is the finest granularity of QoS differentiation in the PDU Session.

A QoS Flow ID (QFI) is used to identify a QoS Flow in the 5G System.

User Plane traffic with the same QFI within a PDU Session receives the same traffic forwarding treatment (e.g. Scheduling, Admission Threshold).

The QFI is carried in an Encapsulation Header on N3 (& N9) i.e. without any changes to the E2E Packet Header.

QFI shall be used for all PDU Session Types.

The QFI shall be unique within a PDU Session.

The QFI may be dynamically assigned or may be equal to the 5QI

Within the 5GS, a QoS Flow is controlled by the SMF and may be pre-configured, or established via the PDU Session Establishment procedure or the PDU Session Modification procedure

The principle for classification and marking of User Plane traffic and mapping of QoS Flows to AN resources is illustrated in Figure 5.7.1.5-1.

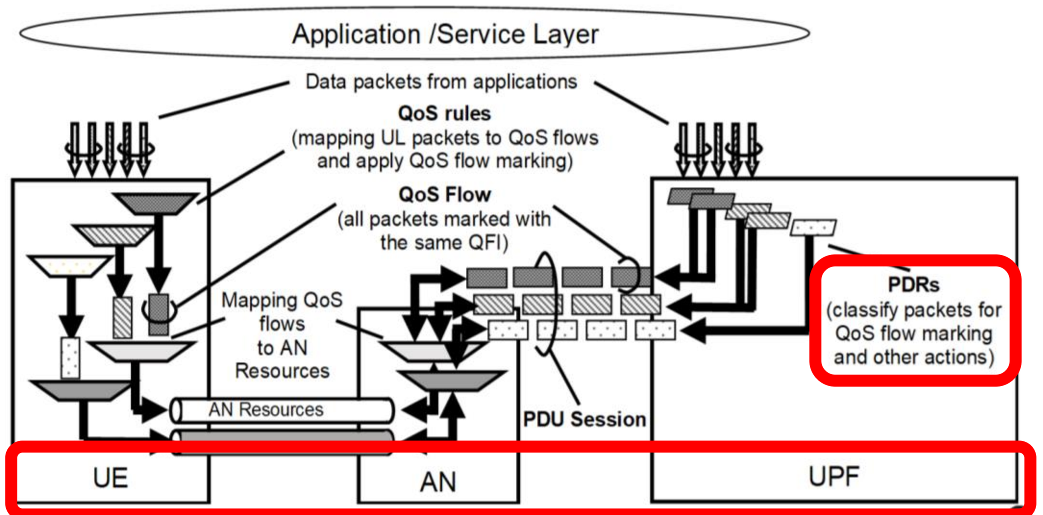


Figure 5.7.1.5-1: The principle for classification and User Plane marking for QoS Flows and mapping to AN Resources

In DL, incoming data packets are classified by the UPF based on the Packet Filter Sets of the DL PDRs in the order of their precedence (without initiating additional N4 signalling). The UPF conveys the classification of the User Plane traffic belonging to a QoS Flow through an N3 (and N9) User Plane marking using a QFI. The AN binds QoS Flows to

Ref. 3GPP 5G System Arch Rel 17: March 2022

The 5G QoS Model is based on QoS Flows.

QoS Profile

A QoS Flow may either be 'GBR' or 'Non-GBR' depending on its QoS profile.

The QoS profile of a QoS Flow is sent to the (R)AN and it contains QoS parameters as described below:

- For each QoS Flow, the QoS Profile shall include the QoS parameters:
- 5G QoS Identifier (5QI); and
- Allocation and Retention Priority (ARP).
- For each Non-GBR QoS Flow only, the QoS profile may also include the QoS parameter:
- Reflective QoS Attribute (RQA).
- For each GBR QoS Flow only, the QoS profile shall also include the QoS parameters:
- Guaranteed Flow Bit Rate (GFBR) - UL and DL; and
- Maximum Flow Bit Rate (MFBR) - UL and DL; and
- In the case of a GBR QoS Flow only, the QoS profile may also include one or more of the QoS parameters:
- Notification control;
- Maximum Packet Loss Rate - UL and DL.

NOTE: In this Release of the specification, the Maximum Packet Loss Rate (UL, DL) is only provided for a GBR QoS flow belonging to Voice media.

- Each QoS profile has one corresponding QoS Flow identifier (QFI) which is not included in the QoS profile itself.
- The usage of a dynamically assigned 5QI for a QoS Flow requires in addition the signalling of the complete 5G QoS characteristics (described in clause 5.7.3) as part of the QoS profile.
- When a standardized or pre-configured 5QI is used for a QoS Flow, some of the 5G QoS characteristics may be signalled as part of the QoS profile (as described in clause 5.7.3).

The principle for classification and marking of User Plane traffic and mapping of QoS Flows to AN resources is illustrated in Figure 5.7.1.5-1.

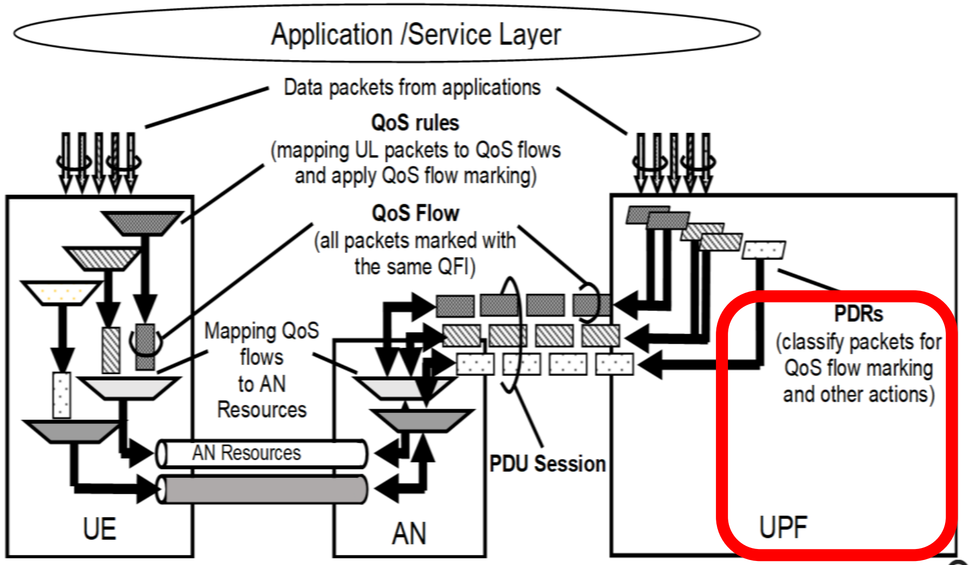


Figure 5.7.1.5-1: The principle for classification and User Plane marking for QoS Flows and mapping to AN Resources

In DL, incoming data packets are classified by the UPF based on the Packet Filter Sets of the DL PDRs in the order of their precedence (without initiating additional N4 signalling). The UPF conveys the classification of the User Plane traffic belonging to a QoS Flow through an N3 (and N9) User Plane marking using a QFI. The AN binds QoS Flows to

Ref. 3GPP TS 23 501 5G System Arch Rel 17: Sept 2021:147

5G QoS 4G vs 5G QoS

Table: Attributes within Packet Detection Rule (PDR)

Attribute		Description	Comment
N4 Session ID		Identifies the N4 session associated to this PDR. NOTE 5.	
Rule ID		Unique identifier to identify this rule.	
Precedence		Determines the order, in which the detection information of all rules is applied.	
Packet Detection Information. NOTE 4.	Source interface	Contains the values "access side", "core side", "SMF", "N6-LAN", "5G VN internal", "MBS internal".	Combination of UE IP address (together with Network instance, if necessary), CN tunnel info, packet filter set, application identifier, Ethernet PDU Session Information and QFI are used for traffic detection. Source interface identifies the interface for incoming packets where the PDR applies, e.g. from access side (i.e. up-link), from core side (i.e. down-link), from SMF, from N6-LAN (i.e. the DN or the local DN), from "5G VN internal" (i.e. local switch), or from "MBS internal" (i.e. local switch for MBS session) (see TS 23.247 [129] for its usage). Details like all the combination possibilities on N3, N9 interfaces are left for stage 3 decision.
	UE IP address	One IPv4 address and/or one IPv6 prefix with prefix length (NOTE 3).	
	Network instance (NOTE 1)	Identifies the Network instance associated with the incoming packet.	
	CN tunnel info	CN tunnel info on N3, N9 interfaces, i.e. F-TEID.	
	Packet Filter Set	Details see clause 5.7.6.	
	Application identifier		
	QoS Flow ID	Contains the value of 5QI or non-standardized QFI.	
	Ethernet PDU Session Information	Refers to all the (DL) Ethernet packets matching an Ethernet PDU session, as further described in clause 5.6.10.2 and in TS 29.244 [65].	
	Framed Route Information	Refers to Framed Routes defined in clause 5.6.14.	
Packet replication and detection carry on information	Packet replication skip information NOTE 7	Contains UE address indication or N19/N6 indication. If the packet matches the packet replication skip information, i.e. source address of the packet is the UE address or the packet has been received on the interface in the packet replication skip information, the UP function neither creates a copy of the packet nor applies the corresponding processing (i.e. FAR, QER, URR). Otherwise the UPF performs a copy and applies the corresponding processing (i.e. FAR, QER, URR).	
NOTE 6	Carry on indication	Instructs the UP function to continue the packet detection process, i.e. lookup of the other PDRs.	
Outer header removal		Instructs the UP function to remove one or more outer header(s) (e.g. IP+UDP+GTP, IP + possibly UDP, VLAN tag), from the incoming packet.	Any extension header shall be stored for this packet.
Forwarding Action Rule ID (NOTE 2)		The Forwarding Action Rule ID identifies a forwarding action that has to be applied.	
Multi-Access Rule ID (NOTE 2)		The Multi-Access Rule ID identifies an action to be applied for handling forwarding for a MA PDU Session.	
List of Usage Reporting Rule ID(s)		Every Usage Reporting Rule ID identifies a measurement action that has to be applied.	
List of QoS Enforcement Rule ID(s)		Every QoS Enforcement Rule ID identifies a QoS enforcement action that has to be applied.	

The principle for classification and marking of User Plane traffic and mapping of QoS Flows to AN resources is illustrated in Figure 5.7.1.5-1.

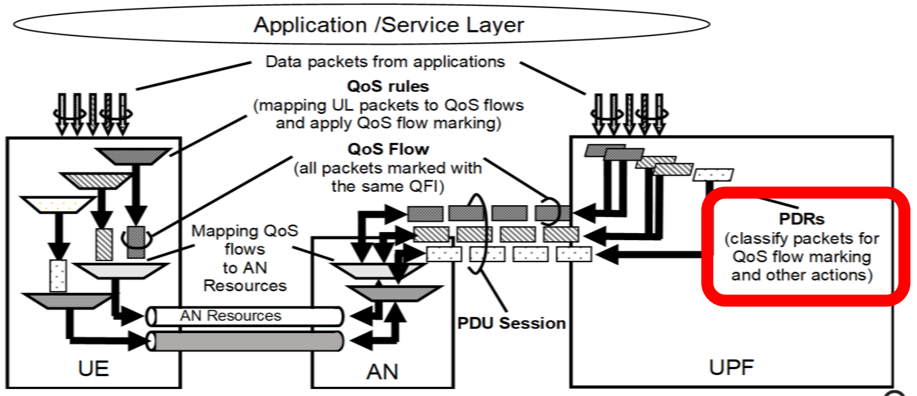


Figure 5.7.1.5-1: The principle for classification and User Plane marking for QoS Flows and mapping to AN Resources

In DL, incoming data packets are classified by the UPF based on the Packet Filter Sets of the DL PDRs in the order of their precedence (without initiating additional N4 signalling). The UPF conveys the classification of the User Plane traffic belonging to a QoS Flow through an N3 (and N9) User Plane marking using a QFI. The AN binds QoS Flows to

NOTE 1: Needed e.g. if:
- UPF supports multiple DNN with overlapping IP addresses;
- UPF is connected to other UPF or AN node in different IP domains.
- UPF "local switch", N6-based forwarding and N19 forwarding is used for different 5G LAN groups.
- UPF "local switch for MBS". The Network instance indicates the MBS session ID.

NOTE 2: Either a FAR ID or a MAR ID is included, not both.

NOTE 3: The SMF may provide an indication asking the UPF to allocate one IPv4 address and/or IPv6 prefix. When asking to provide an IPv6 Prefix the SMF provides also an IPv6 prefix length.

NOTE 4: When in the architecture defined in clause 5.34, a PDR is sent over N16a from SMF to I-SMF, the Packet Detection Information may indicate that CN tunnel info is to be locally determined. This is further defined in clause 5.34.6.

NOTE 5: In the architecture defined in clause 5.34, the rules exchanged between I-SMF and SMF are not associated with a N4 Session ID but are associated with a N16a association.

NOTE 6: Needed in the case of support for broadcast/multicast traffic forwarding using packet replication with SMF-provided PDRs and FARs as described in clause 5.8.2.13.3.2.

NOTE 7: Needed in the case of packet replication with SMF-provided PDRs and FARs as described in clause 5.8.2.13.3.2, to prevent UPF from sending the broadcast/multicast packets back to the source UE or source N19/N6.

5.8.2.11.4 QoS Enforcement Rule

The following table describes the QoS Enforcement Rule (QER) that defines how a packet shall be treated in terms of bit rate limitation and packet marking for QoS purposes. All Packet Detection Rules that refer to the same QER share the same QoS resources, e.g. MFBR.

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Table 5.8.2.11.4-1: Attributes within QoS Enforcement Rule

Attribute	Description	Comment
N4 Session ID	Identifies the N4 session associated to this QER	
Rule ID	Unique identifier to identify this information.	
QoS Enforcement Rule correlation ID (NOTE 1)	An identity allowing the UP function to correlate multiple Sessions for the same UE and APN.	Is used to correlate QoS Enforcement Rules for APN-AMBR enforcement.
Gate status UL/DL	Instructs the UP function to let the flow pass or to block the flow.	Values are: open, close, close after measurement report (for termination action "discard").
Maximum bitrate	The uplink/downlink maximum bitrate to be enforced for the packets.	This field may e.g. contain any one of: - APN-AMBR (for a QER that is referenced by all relevant Packet Detection Rules of all PDN Connections to an APN) (NOTE 1). - Session-AMBR (for a QER that is referenced by all relevant Packet Detection Rules of the PDU Session) - QoS Flow MBR (for a QER that is referenced by all Packet Detection Rules of a QoS Flow) - SDF MBR (for a QER that is referenced by the uplink/downlink Packet Detection Rule of a SDF) - Bearer MBR (for a QER that is referenced by all relevant Packet Detection Rules of a bearer) (NOTE 1).
Guaranteed bitrate	The uplink/downlink guaranteed bitrate authorized for the packets.	This field contains: - QoS Flow GBR (for a QER that is referenced by all Packet Detection Rules of a QoS Flow) - Bearer GBR (for a QER that is referenced by all relevant Packet Detection Rules of a bearer) (NOTE 1).
Averaging window	The time duration over which the Maximum and Guaranteed bitrate shall be calculated.	This is for counting the packets received during the time duration.
Down-link flow level marking	Flow level packet marking in the downlink.	For UPF, this is for controlling the setting of the RQI in the encapsulation header as described in clause 5.7.5.3.
QoS Flow ID	QoS Flow ID to be inserted by the UPF.	The UPF inserts the QFI value in the tunnel header of outgoing packets.
Paging Policy Indicator	Indicates the PPI value the UPF is required to insert in outgoing packets (see clause 5.4.3.2).	PPI applies only for DL traffic. The UPF inserts the PPI in the outer header of outgoing PDU.

Table 5.32.8-1: Structure of ATSSS Rule

Information name	Description	Category	SMF permitted to modify in a PDU context	Scope
ATSSS Rule ID	Unique identifier to identify the ATSSS Rule	Conditional (NOTE 6)	No	PDU context
Rule Precedence	Determines the order in which the ATSSS rule is evaluated in the UE.	Mandatory (NOTE 1)	Yes	PDU context
Traffic Descriptor	*This part defines the Traffic descriptor components for the ATSSS rule.*	Mandatory (NOTE 2)		
Application descriptors	One or more application identities that identify the application(s) generating the traffic (NOTE 3).	Optional	Yes	PDU context
IP descriptors (NOTE 4)	One or more 5-tuples that identify the destination of IP traffic.	Optional	Yes	PDU context
Non-IP descriptors (NOTE 4)	One or more descriptors that identify the destination of non-IP traffic, i.e. of Ethernet traffic.	Optional	Yes	PDU context
Access Selection Descriptor	*This part defines the Access Selection Descriptor components for the ATSSS rule.*	Mandatory		
Steering Mode	Identifies the steering mode that should be applied for the matching traffic and associated parameters.	Mandatory	Yes	PDU context
Steering Mode Indicator	Indicates either autonomous load-balance operation or UE-assistance operation if steering mode is set to "Load Balancing".	Optional	Yes	PDU context
Threshold Values	A Maximum RTT and/or a Maximum Packet Loss Rate.	Optional	Yes	PDU context
Steering Functionality	Identifies whether the MPTCP functionality or the ATSSS-LL functionality should be applied for the matching traffic.	Optional (NOTE 5)	Yes	PDU context

NOTE 1: Each ATSSS rule has a different precedence value from the other ATSSS rules.
NOTE 2: At least one of the Traffic Descriptor components is present.
NOTE 3: An application identity consists of an OSId and an OSAppId.
NOTE 4: An ATSSS rule cannot contain both IP descriptors and Non-IP descriptors.
NOTE 5: If the UE supports only one Steering Functionality, this component is omitted.
NOTE 6: The ATSSS Rule ID shall be present if the UE indicates support of individual ATSSS rule updates.

The principle for classification and marking of User Plane traffic and mapping of QoS Flows to AN resources is illustrated in Figure 5.7.1.5-1.

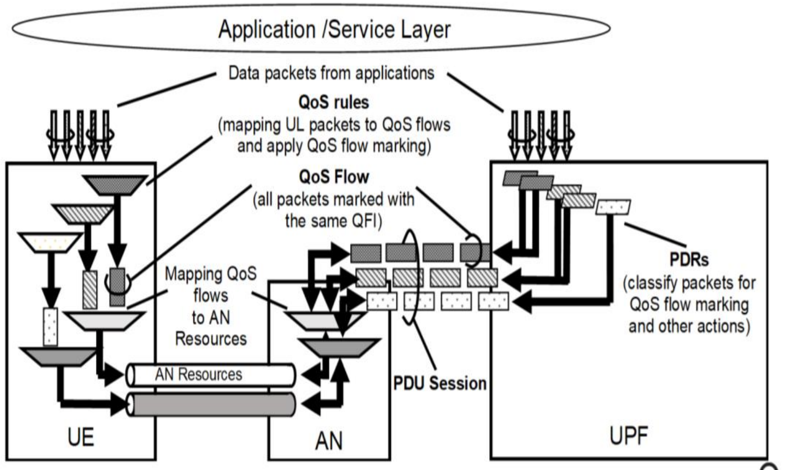

Figure 5.7.1.5-1: The principle for classification and User Plane marking for QoS Flows and mapping to AN Resources

In DL, incoming data packets are classified by the UPF based on the Packet Filter Sets of the DL PDRs in the order of their precedence (without initiating additional N4 signalling). The UPF conveys the classification of the User Plane traffic belonging to a QoS Flow through an N3 (and N9) User Plane marking using a QFI. The AN binds QoS Flows to

5-Tuple : a 5-Tuple refers to a Set of five (5) different Values that includes:

1. a source IP address/
2. IP address Port number,
3. destination IP address/
4. destination Port number and
5. the Protocol in use.

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Table 5.8.2.11.5-1: Attributes within Usage Reporting Rule

At	Attribute	Description	Comment
N4 Session I	N4 Session ID	Identifies the N4 session associated to this URR	
Rule ID	Rule ID	Unique identifier to identify this information.	Used by UPF when reporting usage.
Reporting tri	Reporting triggers	One or multiple of the events can be activated for the generation and reporting of the usage report.	Applicable events include: - Start/stop of traffic detection with/without application instance identifier and deduced SDF filter reporting; Deletion of last PDR for a URR; Periodic measurement threshold reached; Volume/Time/Event measurement threshold reached; Immediate report requested; Measurement of incoming UL traffic; Measurement of discarded DL traffic; MAC address reporting in the UL traffic; unknown destination MAC/IP address; end marker packet has been received.
Periodic mea threshold	Periodic measurement threshold	Defines the point in time for sending a periodic report for this URR (e.g. timeofday).	This allows generation of periodic usage report for e.g. offline charging. It can also be used for realizing the Monitoring time of the usage monitoring feature. It can also be used for realizing the Quota-Idle-Timeout, i.e. to enable the CP function to check whether any traffic has passed during this time.
Volume mea threshold	Volume measurement threshold	Value in terms of uplink and/or downlink and/or total byte-count when the measurement report is to be generated.	
Time measu	Time measurement threshold	Value in terms of the time duration (e.g. in seconds) when the measurement report is to be generated.	
Event measu threshold	Event measurement threshold	Number of events (identified according to a locally configured policy) after which the measurement report is to be generated.	
Inactivity det	Inactivity detection time	Defines the period of time after which the time measurement shall stop, if no packets are received.	Timer corresponding to this duration is restarted at the end of each transmitted packet.
Event based	Event based reporting	Points to a locally configured policy which is identifies event(s) trigger for generating usage report.	
Linked URR	Linked URR ID(s)	Points to one or more other URR ID.	This enables the generation of a combined Usage Report for this and other URRs by triggering their reporting. See clause 5.2.2.4, TS 29.244 [65].
Measuremer	Measurement Method	Indicates the method for measuring the network resources usage, i.e. the data volume, duration, combined volume/duration, or event.	

The principle for classification and marking of User Plane traffic and mapping of QoS Flows to AN resources is illustrated in Figure 5.7.1.5-1.

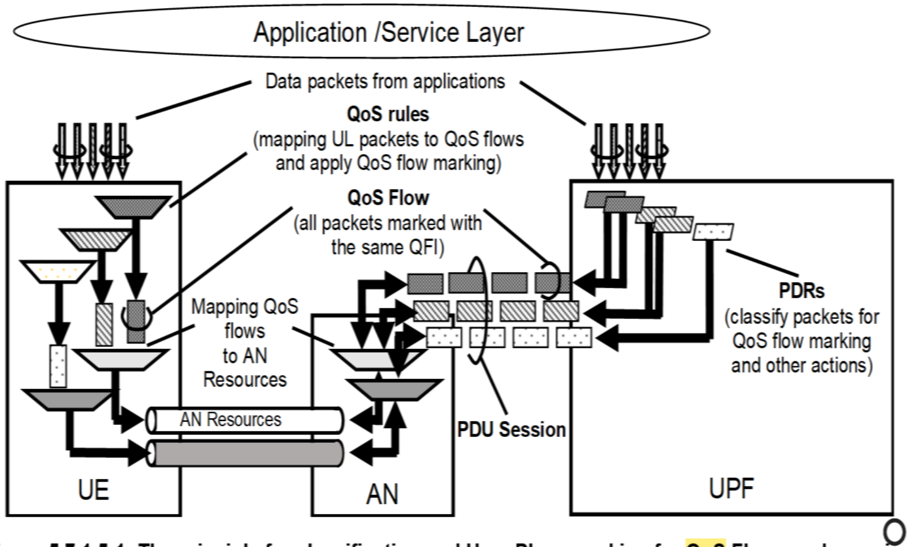

Figure 5.7.1.5-1: The principle for classification and User Plane marking for QoS Flows and mapping to AN Resources

In DL, incoming data packets are classified by the UPF based on the Packet Filter Sets of the DL PDRs in the order of their precedence (without initiating additional N4 signalling). The UPF conveys the classification of the User Plane traffic belonging to a QoS Flow through an N3 (and N9) User Plane marking using a QFI. The AN binds QoS Flows to

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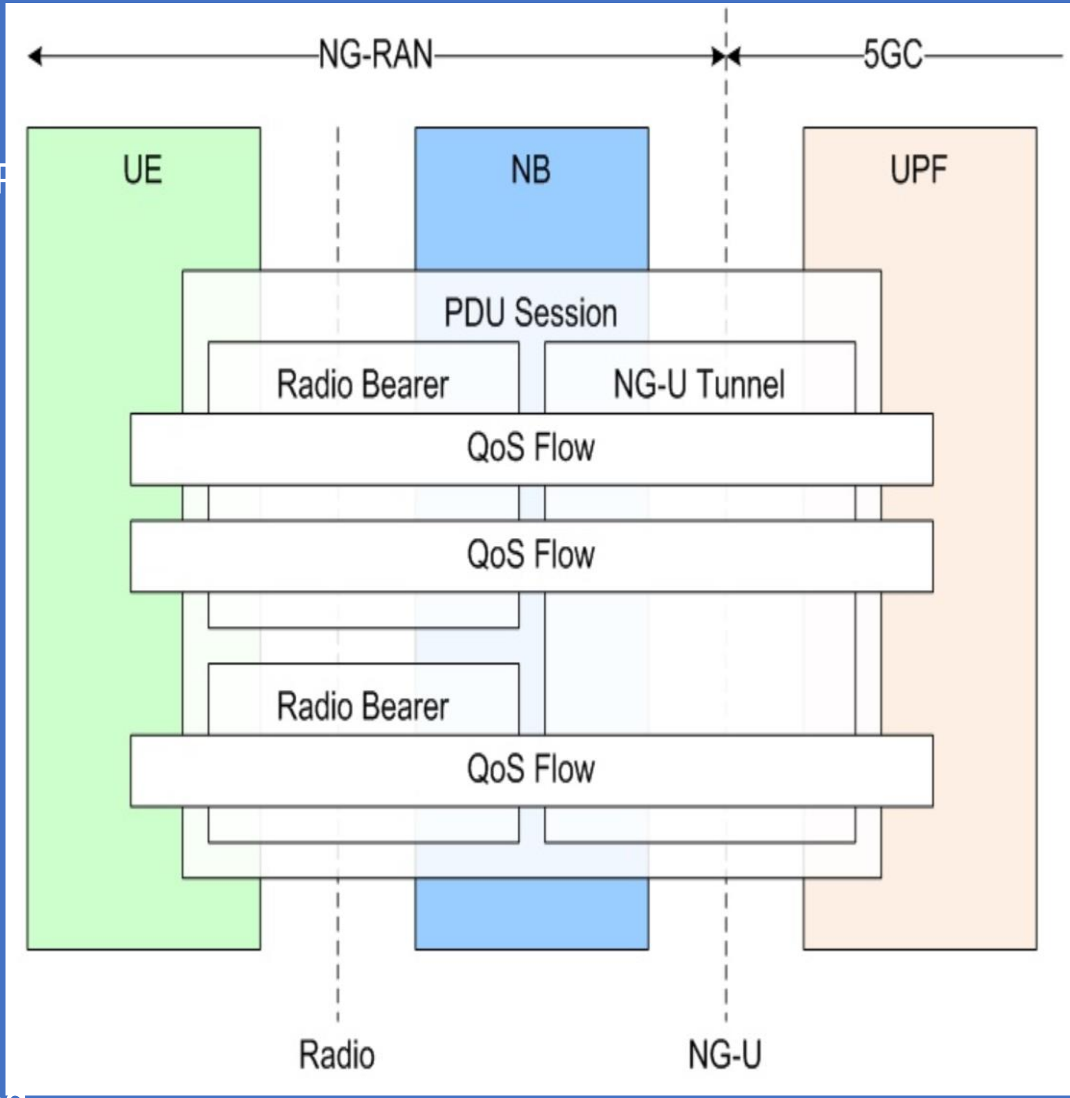
5G NR network QoS architecture

Below You can see the 5G NR network QoS architecture (details in 3GPP 38.300)



For each QoS flow are assigned:

5G QoS Identifier (5QI);
An Allocation and Retention Priority (ARP);

For GBR QoS flow :
Guaranteed Flow Bit Rate (GFBR) for DL (downlink) and UL (uplink);
Maximum Flow Bit Rate (MFBR) for DL (downlink) and UL (uplink) ;
Maximum Packet Loss Rate for DL (downlink) and UL (uplink) ;

For Non-GBR QoS:
Reflective QoS Attribute (RQA);
Requirements for each services of the 5G NR network, (for each assigned 5QI) is strictly regulated by 3GPP TS 23.501 and are presented in the table below

5QI Value	Resource Type	Default Priority Level	Packet Delay Budget (NOTE 3)	Packet Error Rate	Default Maximum Data Burst Volume (NOTE 2)	Default Averaging Window	Example Services
1	GBR (NOTE 1)	20	100 ms (NOTE 11, NOTE 13)	10^{-2}	N/A	2000 ms	Conversational Voice
2		40	150 ms (NOTE 11, NOTE 13)	10^{-3}	N/A	2000 ms	Conversational Video (Live Streaming)
3		30	50 ms (NOTE 11, NOTE 13)	10^{-3}	N/A	2000 ms	Real Time Gaming, V2X messages (see TS 23.287 [121]). Electricity distribution – medium voltage, Process automation monitoring
4		50	300 ms (NOTE 11, NOTE 13)	10^{-6}	N/A	2000 ms	Non-Conversational Video (Buffered Streaming)
65 (NOTE 9, NOTE 12)		7	75 ms (NOTE 7, NOTE 8)	10^{-2}	N/A	2000 ms	Mission Critical user plane Push To Talk voice (e.g. MCPTT)
66 (NOTE 12)		20	100 ms (NOTE 10, NOTE 13)	10^{-2}	N/A	2000 ms	Non-Mission-Critical user plane Push To Talk voice
67 (NOTE 12)		15	100 ms (NOTE 10, NOTE 13)	10^{-3}	N/A	2000 ms	Mission Critical Video user plane
75 (NOTE 14)							
71		56	150 ms (NOTE 11, NOTE 13, NOTE 15)	10^{-6}	N/A	2000 ms	"Live" Uplink Streaming (e.g. TS 26.238 [76])
72		56	300 ms (NOTE 11, NOTE 13, NOTE 15)	10^{-4}	N/A	2000 ms	"Live" Uplink Streaming (e.g. TS 26.238 [76])
73		56	300 ms (NOTE 11, NOTE 13, NOTE 15)	10^{-8}	N/A	2000 ms	"Live" Uplink Streaming (e.g. TS 26.238 [76])
74		56	500 ms (NOTE 11, NOTE 15)	10^{-8}	N/A	2000 ms	"Live" Uplink Streaming (e.g. TS 26.238 [76])
76		56	500 ms (NOTE 11, NOTE 13, NOTE 15)	10^{-4}	N/A	2000 ms	"Live" Uplink Streaming (e.g. TS 26.238 [76])
5	Non-GBR (NOTE 1)	10	100 ms NOTE 10, NOTE 13)	10^{-6}	N/A	N/A	IMS Signalling
6		60	300 ms (NOTE 10, NOTE 13)	10^{-6}	N/A	N/A	Video (Buffered Streaming) TCP-based (e.g. www, e-mail, chat, ftp, p2p file sharing, progressive video, etc.)
7		70	100 ms (NOTE 10, NOTE 13)	10^{-3}	N/A	N/A	Voice, Video (Live Streaming) Interactive Gaming
8		80	300 ms (NOTE 13)	10^{-6}	N/A	N/A	Video (Buffered Streaming) TCP-based (e.g. www, e-mail, chat, ftp, p2p file sharing, progressive video, etc.)
9		90					
10		90	1100ms (NOTE 13) (NOTE 17)	10^{-6}	N/A	N/A	Video (Buffered Streaming) TCP-based (e.g. www, e-mail, chat, ftp, p2p file sharing, progressive video, etc.) and any service that can be used over satellite access type with these characteristics
69 (NOTE 9, NOTE 12)		5	60 ms (NOTE 7, NOTE 8)	10^{-6}	N/A	N/A	Mission Critical delay sensitive signalling (e.g. MC-PTT signalling)
70 (NOTE 12)		55	200 ms (NOTE 7, NOTE 10)	10^{-6}	N/A	N/A	Mission Critical Data (e.g. example services are the same as 5QI 6/8/9)
79		65	50 ms (NOTE 10, NOTE 13)	10^{-2}	N/A	N/A	V2X messages (see TS 23.287 [121])
80		68	10 ms (NOTE 5, NOTE 10)	10^{-6}	N/A	N/A	Low Latency eMBB applications Augmented Reality
82	Delay-critical GBR	19	10 ms (NOTE 4)	10^{-4}	255 bytes	2000 ms	Discrete Automation (see TS 22.261 [2])
83		22	10 ms (NOTE 4)	10^{-4}	1354 bytes (NOTE 3)	2000 ms	Discrete Automation (see TS 22.261 [2]); V2X messages (UE - RSU Platooning, Advanced Driving: Cooperative Lane Change with low LoA. See TS 22.186 [111], TS 23.287 [121])
84		24	30 ms (NOTE 6)	10^{-5}	1354 bytes (NOTE 3)	2000 ms	Intelligent transport systems (see TS 22.261 [2])
85		21	5 ms (NOTE 5)	10^{-5}	255 bytes	2000 ms	Electricity Distribution- high voltage (see TS 22.261 [2]). V2X messages (Remote Driving. See TS 22.186 [111], NOTE 16, see TS 23.287 [121])
86		18	5 ms (NOTE 5)	10^{-4}	1354 bytes	2000 ms	V2X messages (Advanced Driving: Collision Avoidance, Platooning with high LoA. See TS 22.186 [111], TS 23.287 [121])
87		25	5 ms (NOTE 4)	10^{-3}	500 bytes	2000 ms	Interactive Service - Motion tracking data, (see TS 22.261 [2])
88		25	10 ms (NOTE 4)	10^{-3}	1125 bytes	2000 ms	Interactive Service - Motion tracking data, (see TS 22.261 [2])
89		25	15 ms (NOTE 4)	10^{-4}	17000 bytes	2000 ms	Visual content for cloud/edge/split rendering (see TS 22.261 [2])
90		25	20 ms (NOTE 4)	10^{-4}	63000 bytes	2000 ms	Visual content for cloud/edge/split rendering (see TS 22.261 [2])

NOTE 1: A packet which is delayed more than PDB is not counted as lost, thus not included in the PER.

NOTE 2: It is required that default MDBV is supported by a PLMN supporting the related 5QIs.

NOTE 3: The Maximum Transfer Unit (MTU) size considerations in clause 9.3 and Annex C of TS 23.060 [56] are also applicable. IP fragmentation may have impacts to CN PDB, and details are provided in clause 5.6.10.

NOTE 4: A static value for the CN PDB of 1 ms for the delay between a UPF terminating N6 and a 5G-AN should be subtracted from a given PDB to derive the packet delay budget that applies to the radio interface. When a dynamic CN PDB is used, see clause 5.7.3.4.

NOTE 5: A static value for the CN PDB of 2 ms for the delay between a UPF terminating N6 and a 5G-AN should be subtracted from a given PDB to derive the packet delay budget that applies to the radio interface. When a dynamic CN PDB is used, see clause 5.7.3.4.

NOTE 6: A static value for the CN PDB of 5 ms for the delay between a UPF terminating N6 and a 5G-AN should be subtracted from a given PDB to derive the packet delay budget that applies to the radio interface. When a dynamic CN PDB is used, see clause 5.7.3.4.

NOTE 7: For Mission Critical services, it may be assumed that the UPF terminating N6 is located "close" to the 5G_AN (roughly 10 ms) and is not normally used in a long distance, home routed roaming situation. Hence a static value for the CN PDB of 10 ms for the delay between a UFF terminating N6 and a 5G_AN should be subtracted from this PDB to derive the packet delay budget that applies to the radio interface.

NOTE 8: In both RRC Idle and RRC Connected mode, the PDB requirement for these 5QIs can be relaxed (but not to a value greater than 320 ms) for the first packet(s) in a downlink data or signalling burst in order to permit reasonable battery saving (DRX) techniques.

NOTE 9: It is expected that 5QI-65 and 5QI-69 are used together to provide Mission Critical Push to Talk service (e.g. 5QI-5 is not used for signalling). It is expected that the amount of traffic per UE will be similar or less compared to the IMS signalling.

NOTE 10: In both RRC Idle and RRC Connected mode, the PDB requirement for these 5QIs can be relaxed for the first packet(s) in a downlink data or signalling burst in order to permit battery saving (DRX) techniques.

NOTE 11: In RRC Idle mode, the PDB requirement for these 5QIs can be relaxed for the first packet(s) in a downlink data or signalling burst in order to permit battery saving (DRX) techniques.

NOTE 12: This 5QI value can only be assigned upon request from the network side. The UE and any application running on the UE is not allowed to request this 5QI value.

NOTE 13: A static value for the CN PDB of 20 ms for the delay between a UPF terminating N6 and a 5G-AN should be subtracted from a given PDB to derive the packet delay budget that applies to the radio interface.

NOTE 14: This 5QI is not supported in this Release of the specification as it is only used for transmission of V2X messages over MBMS bearers as defined in TS 23.285 [72] but the value is reserved for future use.

NOTE 15: For "live" uplink streaming (see TS 26.238 [76]), guidelines for PDB values of the different 5QIs correspond to the latency configurations defined in TR 26.939 [77]. In order to support higher latency reliable streaming services (above 500ms PDB), if different PDB and PER combinations are needed these configurations will have to use non-standardised 5QIs.

NOTE 16: These services are expected to need much larger MDBV values to be signalled to the RAN. Support for such larger MDBV values with low latency and high reliability is likely to require a suitable RAN configuration, for which, the simulation scenarios in TR 38.824 [112] may contain some guidance.

NOTE 17: The worst case one way propagation delay for GEO satellite is expected to be ~270ms, ~ 21 ms for LEO at 1200km, and 13 ms for LEO at 600km. The UL scheduling delay that needs to be added is also typically 1 RTD e.g. ~540ms for GEO, ~42ms for LEO at 1200km, and ~26 ms for LEO at 600km. Based on that, the 5G-AN Packet delay budget is not applicable for 5QIs that require 5G-AN PDB lower than the sum of these values when the specific types of satellite access are used (see TS 38.300 [27]). 5QI-10 can accommodate the worst case PDB for GEO satellite type.

NOTE: It is preferred that a value less than 64 is allocated for any new standardised 5QI of Non-GBR resource type. This is to allow for option 1 to be used as described in clause 5.7.1.3 (as the QFI is limited to less than 64).

QCI	Resource Type	Priority Level	Packet Delay Budget (NOTE 13)	Packet Error Loss Rate (NOTE 2)	Example Services
1 (NOTE 3)	GBR	2	100 ms (NOTE 1, NOTE 11)	10^{-2}	Conversational Voice
2 (NOTE 3)		4	150 ms (NOTE 1, NOTE 11)	10^{-3}	Conversational Video (Live Streaming)
3 (NOTE 3, NOTE 14)		3	50 ms (NOTE 1, NOTE 11)	10^{-3}	Real Time Gaming, V2X messages Electricity distribution - medium voltage (e.g. clause 7.2.2 of TS 22.261 [51]) Process automation - monitoring (e.g. clause 7.2.2 of TS 22.261 [51])
4 (NOTE 3)		5	300 ms (NOTE 1, NOTE 11)	10^{-6}	Non-Conversational Video (Buffered Streaming)
65 (NOTE 3, NOTE 9, NOTE 12)		0.7	75 ms (NOTE 7, NOTE 8)	10^{-2}	Mission Critical user plane Push To Talk voice (e.g., MCPTT)
66 (NOTE 3, NOTE 12)		2	100 ms (NOTE 1, NOTE 10)	10^{-2}	Non-Mission-Critical user plane Push To Talk voice
67 (NOTE 3, NOTE 12)		1.5	100 ms (NOTE 1, NOTE 10)	10^{-3}	Mission Critical Video user plane
75 (NOTE 14)		2.5	50 ms (NOTE 1)	10^{-2}	V2X messages
71		5.6	150ms (NOTE 1, NOTE 16)	10^{-6}	"Live" Uplink Streaming (e.g. TS 26.238 [53])
72		5.6	300ms (NOTE 1, NOTE 16)	10^{-4}	"Live" Uplink Streaming (e.g. TS 26.238 [53])
73		5.6	300ms (NOTE 1, NOTE 16)	10^{-8}	"Live" Uplink Streaming (e.g. TS 26.238 [53])
74		5.6	500ms (NOTE 1, NOTE 16)	10^{-8}	"Live" Uplink Streaming (e.g. TS 26.238 [53])
76		5.6	500ms (NOTE 1, NOTE 16)	10^{-4}	"Live" Uplink Streaming (e.g. TS 26.238 [53])
5 (NOTE 3)	Non-GBR	1	100 ms (NOTE 1, NOTE 10)	10^{-6}	IMS Signalling
6 (NOTE 4)		6	300 ms (NOTE 1, NOTE 10)	10^{-6}	Video (Buffered Streaming) TCP-based (e.g., www, e-mail, chat, ftp, p2p file sharing, progressive video, etc.)
7 (NOTE 3)		7	100 ms (NOTE 1, NOTE 10)	10^{-3}	Voice, Video (Live Streaming) Interactive Gaming
8 (NOTE 5)		8	300 ms (NOTE 1)	10^{-6}	Video (Buffered Streaming) TCP-based (e.g., www, e-mail, chat, ftp, p2p file sharing, progressive video, etc.)
9 (NOTE 6)		9			
69 (NOTE 3, NOTE 9, NOTE 12)		0.5	60 ms (NOTE 7, NOTE 8)	10^{-6}	Mission Critical delay sensitive signalling (e.g., MC-PTT signalling, MC Video signalling)
70 (NOTE 4, NOTE 12)		5.5	200 ms (NOTE 7, NOTE 10)	10^{-6}	Mission Critical Data (e.g. example services are the same as QCI 6/8/9)
79 (NOTE 14)		6.5	50 ms (NOTE 1, NOTE 10)	10^{-2}	V2X messages
80 (NOTE 3)		6.8	10 ms (NOTE 10, NOTE 15)	10^{-6}	Low latency eMBB applications (TCP/UDP-based); Augmented Reality

NOTE 1: A delay of 20 ms for the delay between a PCEF and a radio base station should be subtracted from a given PDB to derive the packet delay budget that applies to the radio interface. This delay is the average between the case where the PCEF is located "close" to the radio base station (roughly 10 ms) and the case where the PCEF is located "far" from the radio base station, e.g. in case of roaming with home routed traffic (the one-way packet delay between Europe and the US west coast is roughly 50 ms). The average takes into account that roaming is a less typical scenario. It is expected that subtracting this average delay of 20 ms from a given PDB will lead to desired end-to-end performance in most typical cases. Also, note that the PDB defines an upper bound. Actual packet delays - in particular for GBR traffic - should typically be lower than the PDB specified for a QCI as long as the UE has sufficient radio channel quality.

NOTE 2: The rate of non congestion related packet losses that may occur between a radio base station and a PCEF should be regarded to be negligible. A PELR value specified for a standardized QCI therefore applies completely to the radio interface between a UE and radio base station.

NOTE 3: This QCI is typically associated with an operator controlled service, i.e., a service where the SDF aggregate's uplink / downlink packet filters are known at the point in time when the SDF aggregate is authorized. In case of E-UTRAN this is the point in time when a corresponding dedicated EPS bearer is established / modified.

NOTE 4: If the network supports Multimedia Priority Services (MPS) then this QCI could be used for the prioritization of non real-time data (i.e. most typically TCP-based services/applications) of MPS subscribers.

NOTE 5: This QCI could be used for a dedicated "premium bearer" (e.g. associated with premium content) for any subscriber / subscriber group. Also in this case, the SDF aggregate's uplink / downlink packet filters are known at the point in time when the SDF aggregate is authorized. Alternatively, this QCI could be used for the default bearer of a UE/PDN for "premium subscribers".

NOTE 6: This QCI is typically used for the default bearer of a UE/PDN for non privileged subscribers. Note that AMBR can be used as a "tool" to provide subscriber differentiation between subscriber groups connected to the same PDN with the same QCI on the default bearer.

NOTE 7: For Mission Critical services, it may be assumed that the PCEF is located "close" to the radio base station (roughly 10 ms) and is not normally used in a long distance, home routed roaming situation. Hence delay of 10 ms for the delay between a PCEF and a radio base station should be subtracted from this PDB to derive the packet delay budget that applies to the radio interface.

NOTE 8: In both RRC Idle and RRC Connected mode, the PDB requirement for these QCIs can be relaxed (but not to a value greater than 320 ms) for the first packet(s) in a downlink data or signalling burst in order to permit reasonable battery saving (DRX) techniques.

NOTE 9: It is expected that QCI-65 and QCI-69 are used together to provide Mission Critical Push to Talk service (e.g., QCI-5 is not used for signalling for the bearer that utilizes QCI-65 as user plane bearer). It is expected that the amount of traffic per UE will be similar or less compared to the IMS signalling.

NOTE 10: In both RRC Idle and RRC Connected mode, the PDB requirement for these QCIs can be relaxed for the first packet(s) in a downlink data or signalling burst in order to permit battery saving (DRX) techniques.

NOTE 11: In RRC Idle mode, the PDB requirement for these QCIs can be relaxed for the first packet(s) in a downlink data or signalling burst in order to permit battery saving (DRX) techniques.

NOTE 12: This QCI value can only be assigned upon request from the network side. The UE and any application running on the UE is not allowed to request this QCI value.

NOTE 13: Packet delay budget is not applicable on NB-IoT or when Enhanced Coverage is used for WB-E-UTRAN (see TS 36.300 [19]).

NOTE 14: This QCI could be used for transmission of V2X messages as defined in TS 23.285 [48].

NOTE 15: A delay of 2 ms for the delay between a PCEF and a radio base station should be subtracted from the given PDB to derive the packet delay budget that applies to the radio interface.

NOTE 16: For "live" uplink streaming (see TS 26.238 [53]), guidelines for PDB values of the different QCIs correspond to the latency configurations defined in TR 26.939 [54]. In order to support higher latency reliable streaming services (above 500ms PDB), if different PDB and PELR combinations are needed these configurations will have to use non-standardised QCIs.

QCI	Resource Type	Priority Level	Packet Delay Budget (NOTE B1)	Packet Error Loss Rate (NOTE B2)	Maximum Data Burst Volume (NOTE B1)	Data Rate Averaging Window	Example Services
82 (NOTE B6)	GBR	1.9	10 ms (NOTE B4)	10^{-4} (NOTE B3)	255 bytes	2000 ms	Discrete Automation (TS 22.278 [38], clause 8 bullet g, and TS 22.261 [51], table 7.2.2-1, "small packets")
83 (NOTE B6)		2.2	10 ms (NOTE B4)	10^{-4} (NOTE B3)	1354 bytes (NOTE B5)	2000 ms	Discrete Automation (TS 22.278 [38], clause 8 bullet g, and TS 22.261 [51], table 7.2.2-1, "big packets")
84 (NOTE B6)		2.4	30 ms (NOTE B7)	10^{-5} (NOTE B3)	1354 bytes (NOTE B5)	2000 ms	Intelligent Transport Systems (TS 22.278 [38], clause 8, bullet h, and TS 22.261 [51], table 7.2.2)
85 (NOTE B6)		2.1	5 ms (NOTE B8)	10^{-5} (NOTE B3)	255 bytes	2000 ms	Electricity Distribution- high voltage (TS 22.278 [38], clause 8, bullet i, and TS 22.261 [51], table 7.2.2 and Annex D, clause D.4.2)

NOTE B1: The PDB applies to bursts that are not greater than Maximum Data Burst Volume.

NOTE B2: This Packet Error Loss Rate includes packets that are not successfully delivered over the access network plus those packets that comply with the Maximum Data Burst Volume and GBR requirements but which are not delivered within the Packet Delay Budget.

NOTE B3: Data rates above the GBR, or, bursts larger than the Maximum Data Burst Volume, are treated as best effort, and, in order to serve other packets and meet the PELR, this can lead to them being discarded.

NOTE B4: A delay of 1 ms for the delay between a PCEF and a radio base station should be subtracted from a given PDB to derive the packet delay budget that applies to the radio interface.

NOTE B5: This Maximum Data Burst Volume value is set to 1354 bytes to avoid IP fragmentation on an IPv6 based, IPSec protected GTP tunnel to the eNB (the value is calculated as in Annex C of TS 23.060 [12] and further reduced by 4 bytes to allow for the usage of a GTP-U extension header).

NOTE B6: This QCI is typically associated with a dedicated EPS bearer.

NOTE B7: A delay of 5 ms for the delay between a PCEF and a radio base station should be subtracted from a given PDB to derive the packet delay budget that applies to the radio interface.

NOTE B8: A delay of 2 ms for the delay between a PCEF and a radio base station should be subtracted from a given PDB to derive the packet delay budget that applies to the radio interface.

3GPP RAN & O-RAN

Stand-alone (SA) - NR-U (NR-Unlicensed) connected to 5GC.

This Scenario targets NPN

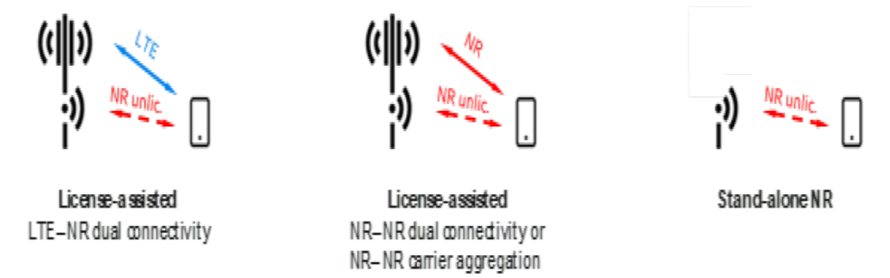


Fig. 3.10. License-assisted (left and middle) and stand-alone (right) operation of NR in unlicensed spectra.

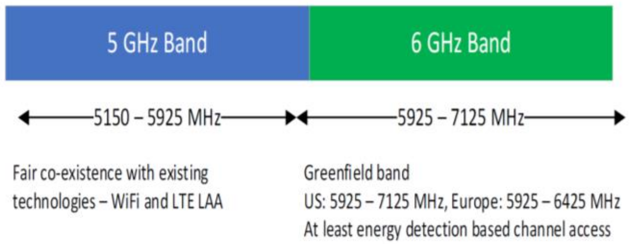


Fig. 3.9. Spectrum priorities for NR-U.

In 3GPP Rel. 16, NR was extended to support operation also in Un-licensed Spectra, with focus on the 5 GHz (5150-5925 GHz) & 6 GHz (5925 – 7150 GHz) bands (Figure 3.9).

- In contrast to LTE, which only supports License-Assisted-Access (LAA) operation in Un-licensed Spectrum,

- NR supports both LAA & Stand-alone (SA) Un-licensed Operation, see Figure 310.

In the case of LAA, a NR carrier in unlicensed spectrum is always operating jointly with a carrier in licensed spectrum, with the carrier in licensed spectrum used for initial access and mobility.

- The licensed carrier can be an NR carrier, but it can also be an LTE carrier. Dual connectivity is used in case of the licensed carrier using LTE. If the licensed carrier is using NR, either dual connectivity or carrier aggregation can be used between the licensed and unlicensed carrier.

In case of SA operation, an NR carrier in Un-licensed spectrum operates without support of a licensed carrier.

Thus, initial access and mobility are handled entirely using unlicensed spectra.

- The 5 GHz band is used by existing Technologies such as Wi-Fi & LTE-based LAA and it was a requirement, for the design of NR-U, or NR in Un-licensed spectrum,

Ref. 5G Americas, 3GPP Rel 16 & 17, & Beyond, Jan 2021: 34

The frequency ranges in which NR can operate according to this version of the specification are identified as described in Table 5.1-1.

Table 5.1-1: Definition of frequency ranges

Frequency range designation	Corresponding frequency range
FR1	410 MHz – 7125 MHz
FR2	24250 MHz – 52600 MHz

NR is designed to operate in the FR2 operating bands defined in Table 5.2-1.

Table 5.2-1: NR operating bands in FR2

Operating Band	Uplink (UL) operating band BS receive UE transmit F_{UL_low} – F_{UL_high}	Downlink (DL) operating band BS transmit UE receive F_{DL_low} – F_{DL_high}	Duplex Mode
n257	26500 MHz – 29500 MHz	26500 MHz – 29500 MHz	TDD
n258	24250 MHz – 27500 MHz	24250 MHz – 27500 MHz	TDD
n259	39500 MHz – 43500 MHz	39500 MHz – 43500 MHz	TDD
n260	37000 MHz – 40000 MHz	37000 MHz – 40000 MHz	TDD
n261	27500 MHz – 28350 MHz	27500 MHz – 28350 MHz	TDD
n262	47200 MHz – 48200 MHz	47200 MHz – 48200 MHz	TDD

Supplementary UL & DL (SUL & SDL)

To improve UL coverage for high frequency scenarios, SUL can be configured. With SUL, the UE is configured with 2 ULs for one (1) DL of the same cell as depicted on Figure B.1-1 below:

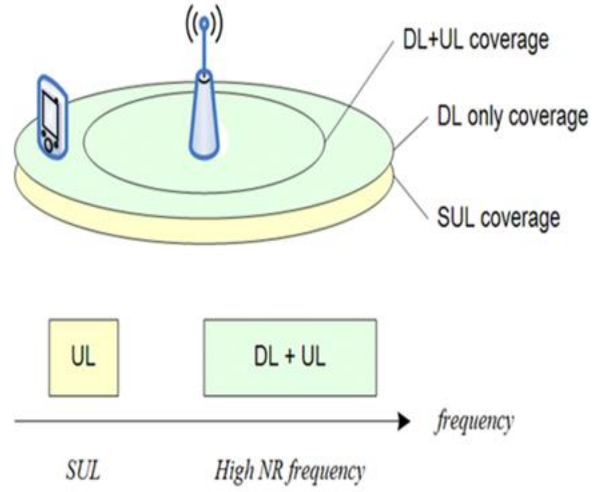


Figure B.1-1: Example of Supplementary Uplink

In case of FDD System, UL frequency is different from DL frequency. Thus, when Radio Resource restriction scenario is discussed, care should be taken by considering these variations e.g. Frequency used for both DL/ UL, UL only or DL only.

5G System introduces further flexibility in using Frequency Band, e.g. SUL (Supplementary UL) & SDL (Supplementary DL) can be used to replace the base frequency band, If the SUL &/or SDL band is restricted for a certain Network Slice (SST), some UEs may experience reduced coverage for the Network Slice.

Aspects related to carrier aggregation also needs to be considered similarly, because it is used to support QoS requirement by using different combination of DL bands & UL bands, e.g. using three DL bands together with one UL bands to boost downlink data rate.

3GPP RAN and O-RAN Alliance

O-RAN.WG1.Slicing-Architecture-v06.00

Technical Specification

O-RAN Working Group 1
Slicing Architecture

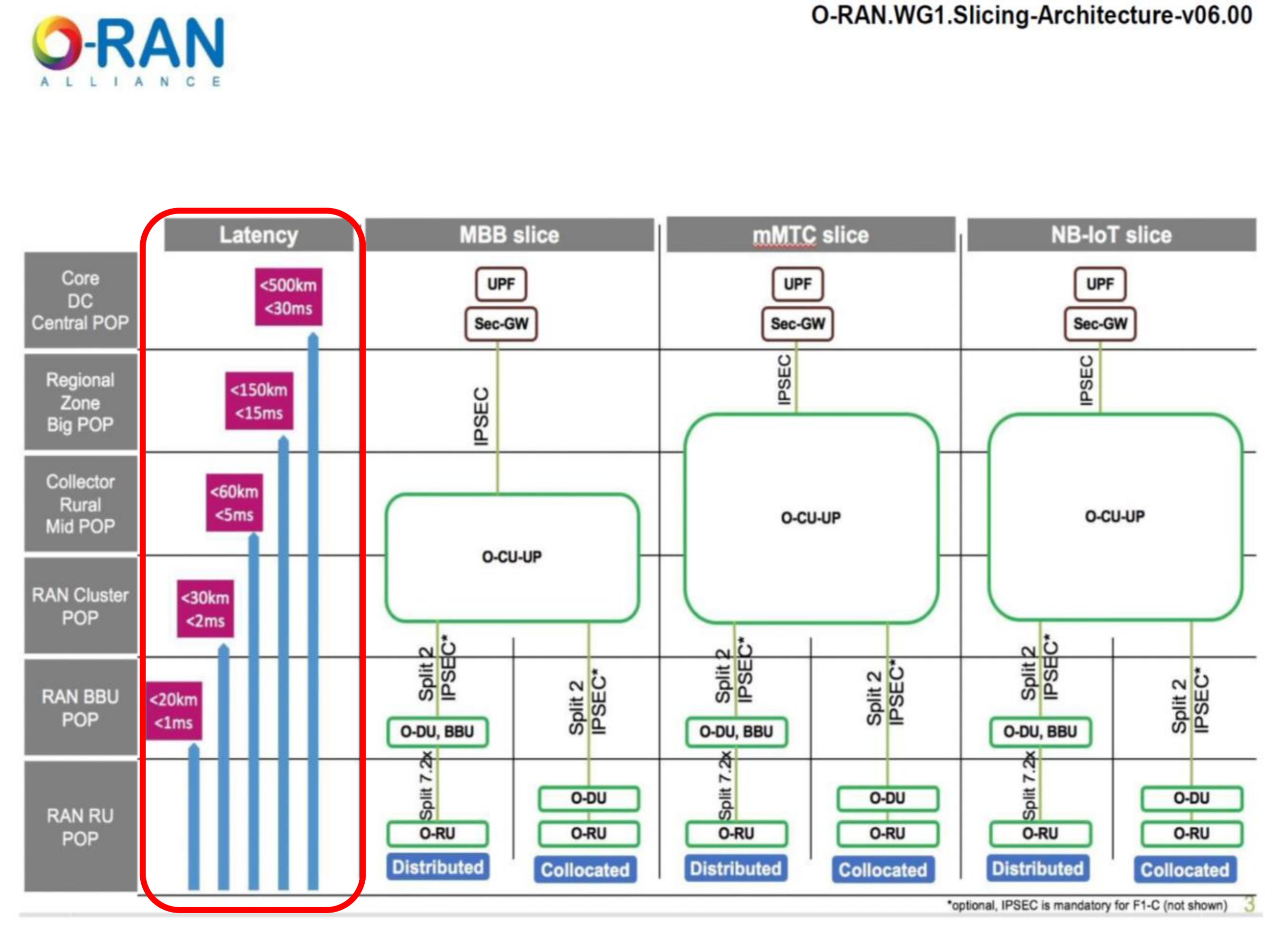


Figure : Diagram of network location of O-RAN instances with relevant domains for use cases

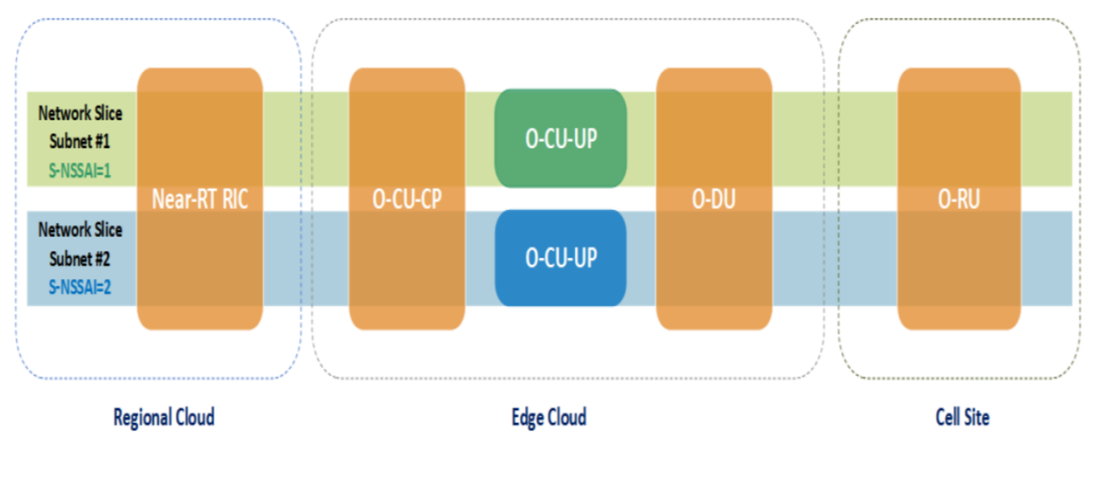


Figure : Example O-RAN Slicing Deployment

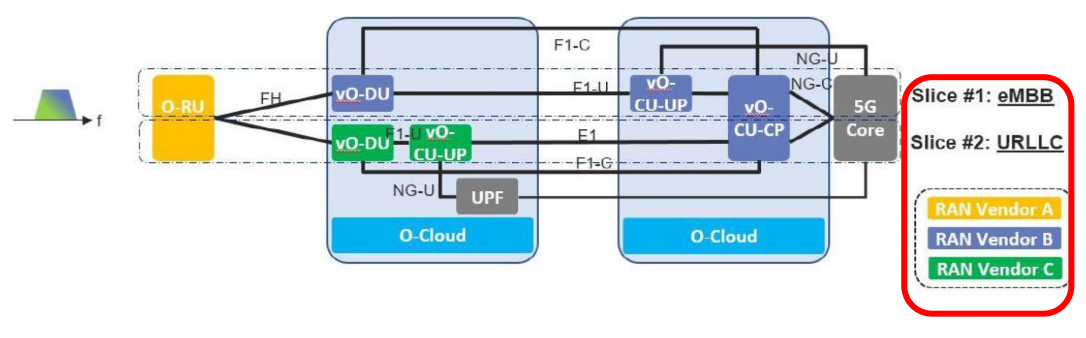


Figure : Multi-vendor Slices

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Table : O-RAN Slice Subnet Instance Creation Use Case

Use Case Stage	Evolution / Specification	<<Uses>> Related use
Goal	Creation of a new O-RAN network slice subnet instance (O-NSSI) or use an existing O-NSSI to satisfy the RAN slice subnet related requirements (see clause 5.1.2 in TS 28.531 [6]).	
Actors and Roles	NSSMS_C such as NSMF, who acts as an example network slice subnet management service consumer. NSSMS_P such as NSSMF, who acts as an example of network slice subnet management service provider. NFMS_P such as SMO OAM Functions or NFMF who acts as an example of network function management service provider. O-Cloud M&O, who acts as O-Cloud management and orchestration provider within SMO. Non-RT RIC O-RAN Network Functions: NFs such as Near-RT RIC, O-CU-CP, O-CU-UP, O-DU and O-RU.	
Assumptions	NSSMS_P is aware of O-Cloud M&O to manage the lifecycle of VNFs and interconnection between the VNFs and PNFs.	
Pre conditions	VNF packages for virtualized O-RAN network functions to be included in the O-RAN slice subnet instance have been already on-boarded.	
Begins when	NSSMS_P receives request for a network slice subnet instance. The request contains network slice subnet related requirements.	
Step 1 (M)	NSSMS_P checks the feasibility of the request, based on the received network slice subnet related requirements.	O-RAN Slice Subnet Feasibility Check
Step 2 (M)	NSSMS_P decides to create a new O-NSSI or use an existing O-NSSI.	
Step 3 (M)	If an existing O-NSSI is decided to be used, NSSMS_P may trigger modification of the existing O-NSSI to satisfy the network slice subnet related requirements. Go to "Step 11". Otherwise, NSSMS_P triggers creation of a new O-NSSI, continue with Step 4	O-RAN Slice Subnet Instance Modification Use Case
Step 4 (M)	NSSMS_P derives the requirements for the constituent NSSI(s).	
Step 5 (O)	If the required O-NSSI contains constituent NSSI(s) managed by other NSSMS_P(s), NSSMS_P may trigger creation of respective constituent NSSI(s) through other NSSMS_P(s) which manages the constituent NSSI(s). In that case, NSSMS_P receives the constituent NSSI information from the other NSSMS_P(s) and associates the constituent NSSI(s) with the required O-NSSI.	(O-RAN) Slice Subnet Instance Creation Use Case (to create constituent (O-)NSSI(s) managed by other NSSMS_P(s))
Step 6 (M)	NSSMS_P determines the service related requirements and triggers a service request to O-Cloud M&O for instantiation of virtual O-RAN network functions and virtual links within the determined O-Cloud(s). Based on the service request, O-Cloud M&O performs corresponding NF instantiation procedures and virtual link establishment.	FFS in WG6
Step 7 (M)	NSSMS_P associates the service response received from O-Cloud M&O with the corresponding O-NSSI.	FFS in WG6
Step 8 (M)	NSSMS_P uses (O-RAN) NF provisioning service exposed by NFMS_P to configure (O-)NSSI constituents.	FFS in WG1
Step 9 (M)	NSSMS_P configures the O-NSSI MOI with each constituent (O-)NSSI MOI identifier.	FFS in WG1
Step 10 (M)	NSSMS_P triggers O-RAN TN Manager coordination procedure to establish necessary links such as for A1, E2, and midhaul and fronthaul connectivity.	FFS in WG9
Step 11 (M)	NSSMS_P notifies Non-RT RIC with network slice subnet requirements and respective O-NSSI information.	FFS in WG2
Step 12 (M)	NSSMS_P notifies NSSMS_C with the resulting status of this process and relevant O-NSSI information.	
Ends when	O-RAN O-NSSI and relevant O-RAN NFs are created, and Non-RT RIC is configured with slice requirements and O-NSSI information.	
Exceptions	One of the steps identified above fails.	
Post Conditions	O-NSSI is ready to satisfy the network slice subnet related requirements.	
Traceability	REQ-SL-FUN14, REQ-SL-FUN20 - REQ-SL-FUN27	

O-RAN Alliance

O-RAN.WG1.Slicing-Architecture-v06.00

Technical Specification

O-RAN Working Group 1
Slicing Architecture

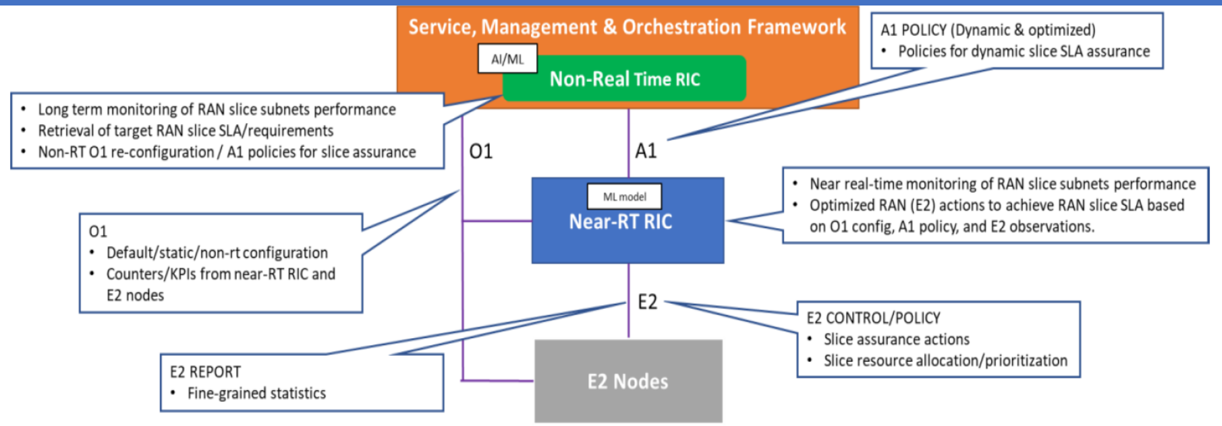

Figure : RAN Slice SLA Assurance use case overview

The more detailed functions provided by the entities for RAN slice SLA assurance are listed as below:

1) Non-RT RIC:
   a) Retrieve RAN slice SLA target from respective entities such as SMO, NSSMF
   b) Long term monitoring of RAN slice subnet performance measurements
   c) Training of potential ML models that will be deployed in Near-RT RIC for optimized slice assurance
   d) Support deployment and update of AI/ML models into Near-RT RIC
   e) Send A1 policies and enrichment information to Near-RT RIC to drive slice assurance

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O-RAN.WG1.Slicing-Architecture-v06.00
Technical Specification
O-RAN Working Group 1
Slicing Architecture

The Option 2 depicts the expectation of the target capabilities of the systems, including capabilities on the Option 1.

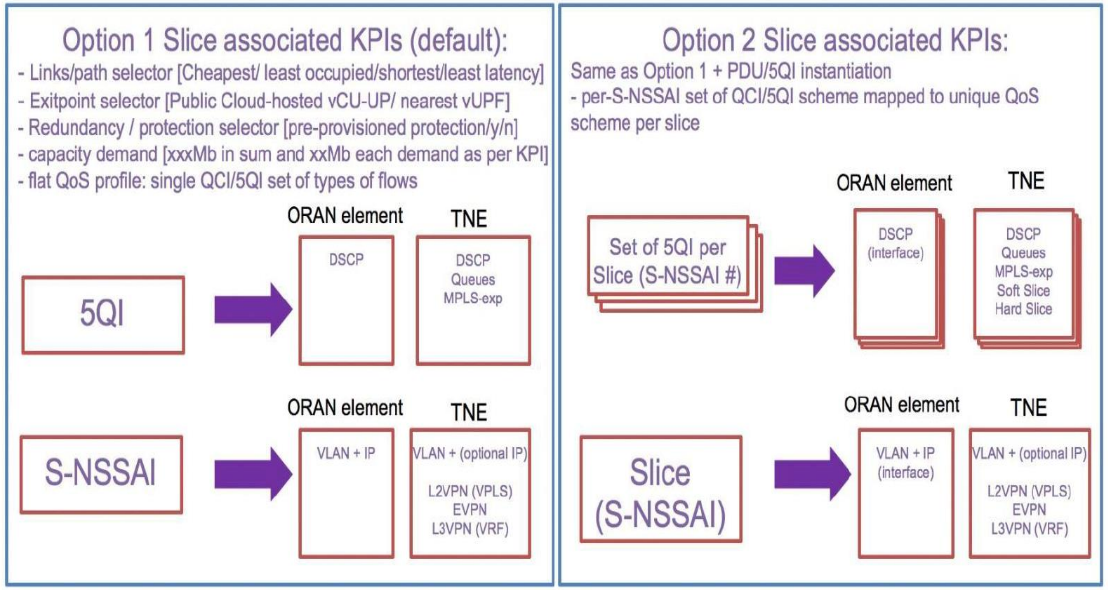

Figure : Options for slicing, demapping orthogonal plane of 5QI per slice in Option 1 and multiple planes of 5QI as attribute per planes of slices

For Phase 1 following constrains are assumed:

1) Single operator with one O-NSSI MBB, one O-NSSI mMTC, one O-NSSI NB-IoT slice
2) Fix mapping of slices inter to intra – DC

** 5QI QoS Identifiers, the Priority Level (if explicitly signaled), and other NG-RAN traffic parameters (e.g., ARP) in O-RAN and Core domains mapped to DSCP and ToS or CoS parameters, aligned with TN domain with accordance to 3GPP NRM in TS 28.541, with the flow depicted in the chart below:

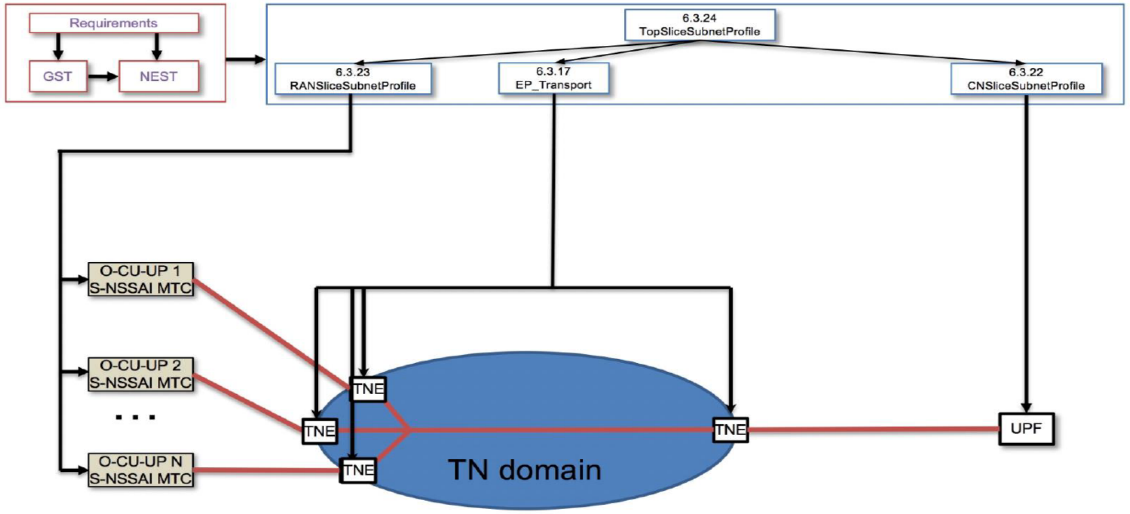

Figure : Diagram of profiles information model parameters mapped to the domains to form a slice

According to these parameters, the relation of RANSliceSubnetProfile and RANSliceSubnetProfile with VLAN and IP mapping could be established with corresponding EP_Transport VLAN and IP mapping, allowing TN domain to perform separation allocation of resources per slice.

Phase 2 assumes the following constrains:

1) Single operator with enterprise slices use case
2) Number of slices: many.
3) Multiple exit points and multiple UPFs
4) Per-slice (tenant) 5QI<>DSCP<>QoS model in TN domain

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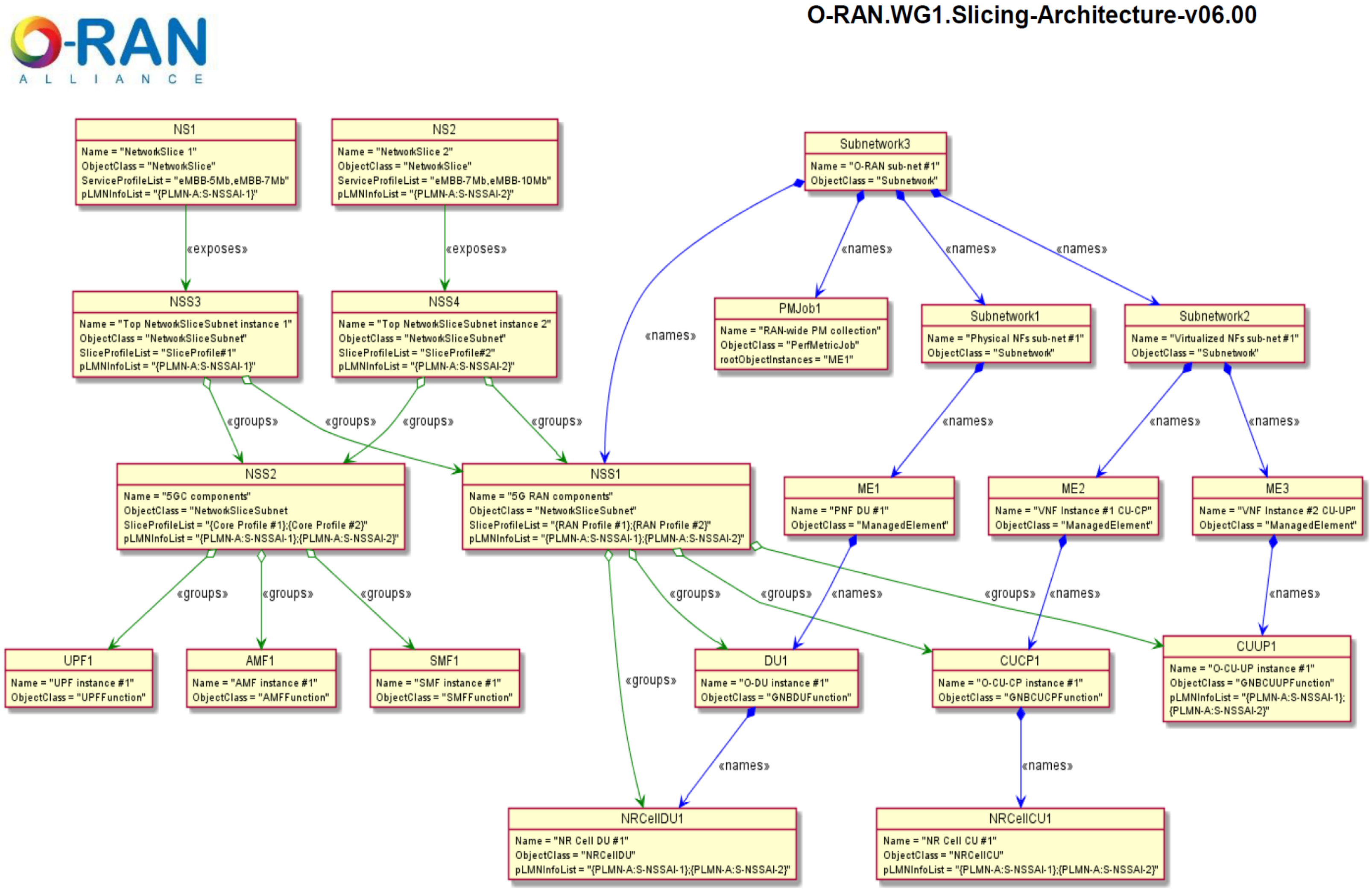
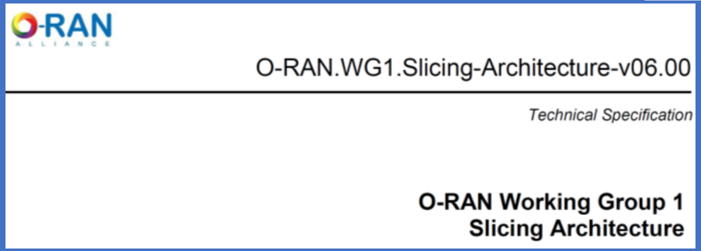


Figure : Slicing Instance Example


O-RAN

O-RAN.WG1.Slicing-Architecture-v06.00

Technical Specification

O-RAN Working Group 1
Slicing Architecture

3GPP RAN and O-RAN Alliance

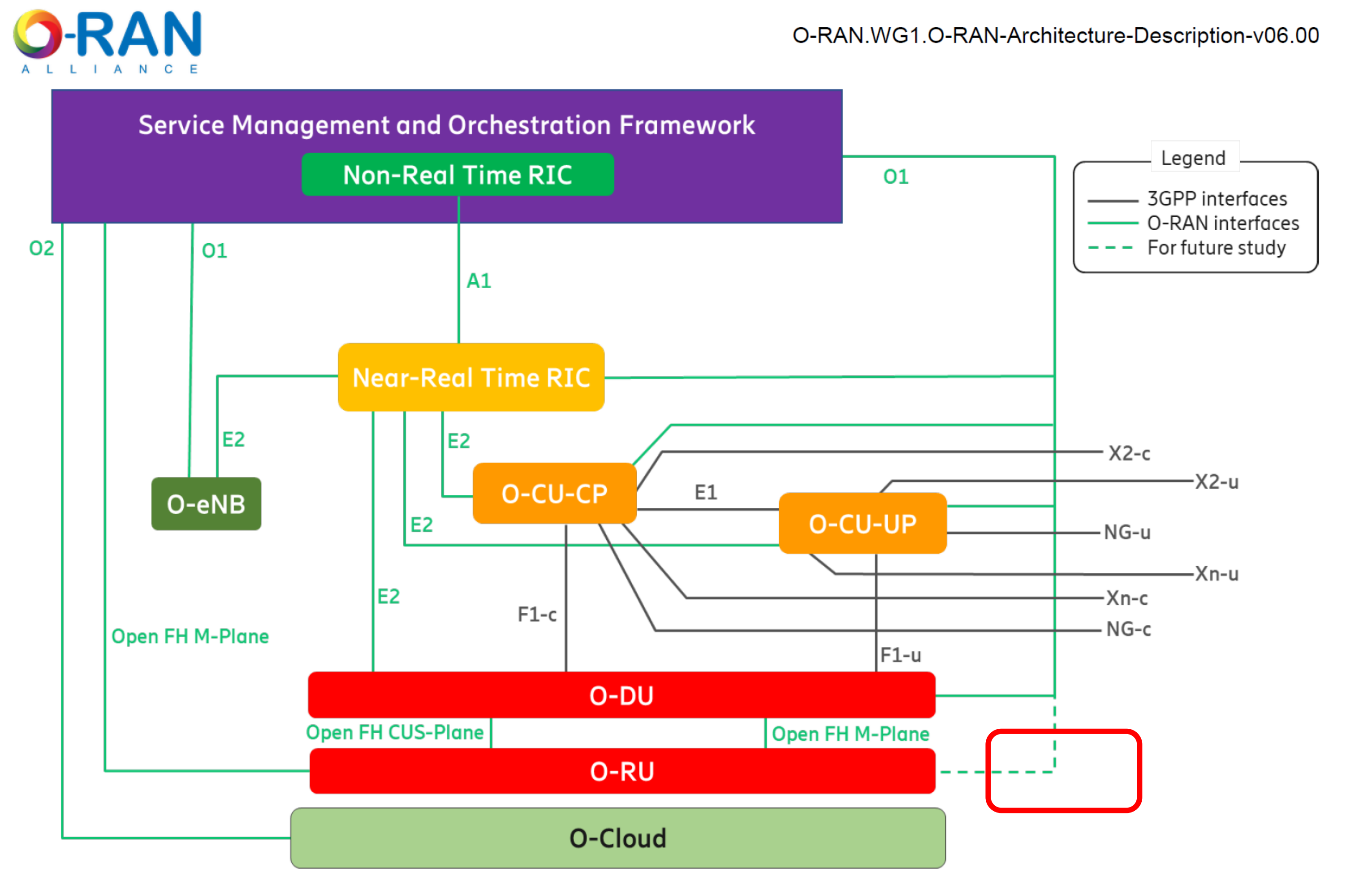
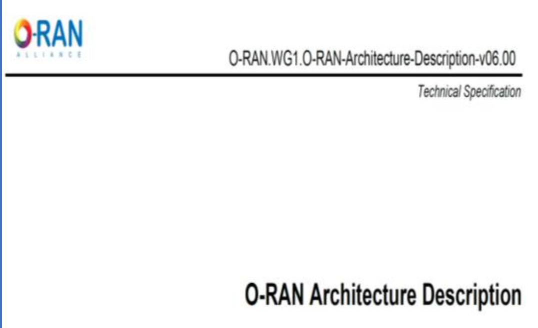


Figure : Logical Architecture of O-RAN



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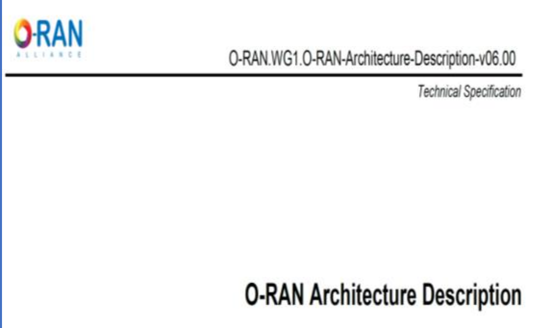

that enable rApps" outside the Non-RT RIC (i.e., into the SMO Framework), as shown in this figure, denotes that the R1 services being exposed may either come from the Non-RT RIC or the SMO.

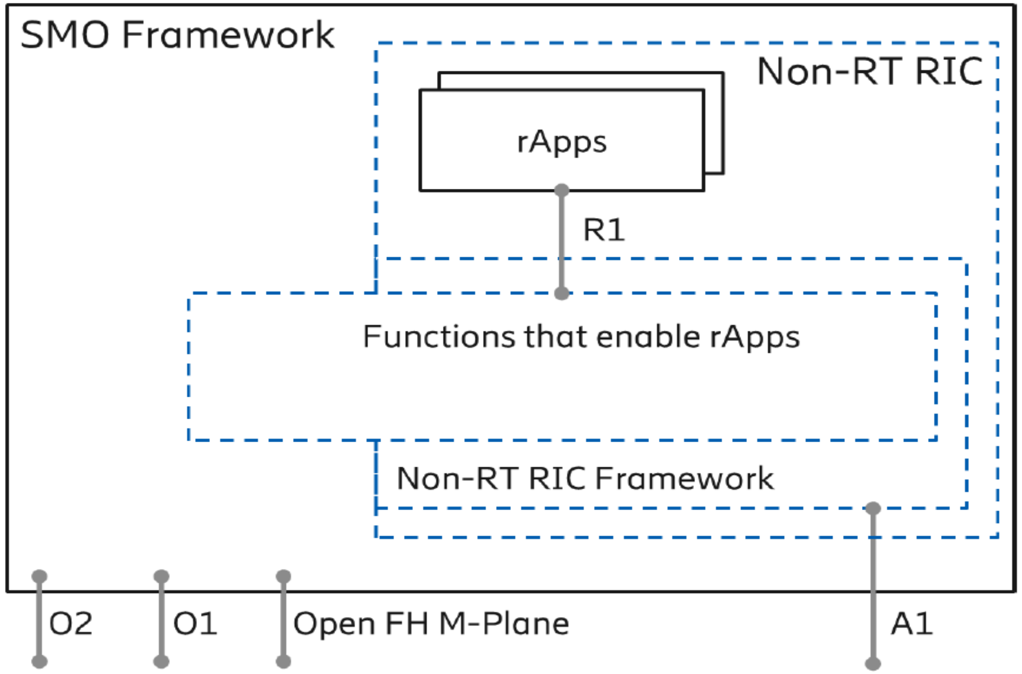

Figure : Exposure of SMO and Non-RT RIC Framework Services

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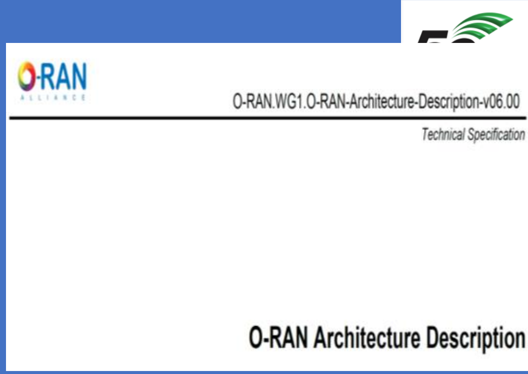

A.3 Near-RT RIC

The Near-RT RIC can control multiple E2 Nodes or can control a single E2 Node. The following figures show two implementation options of Near-RT RIC.

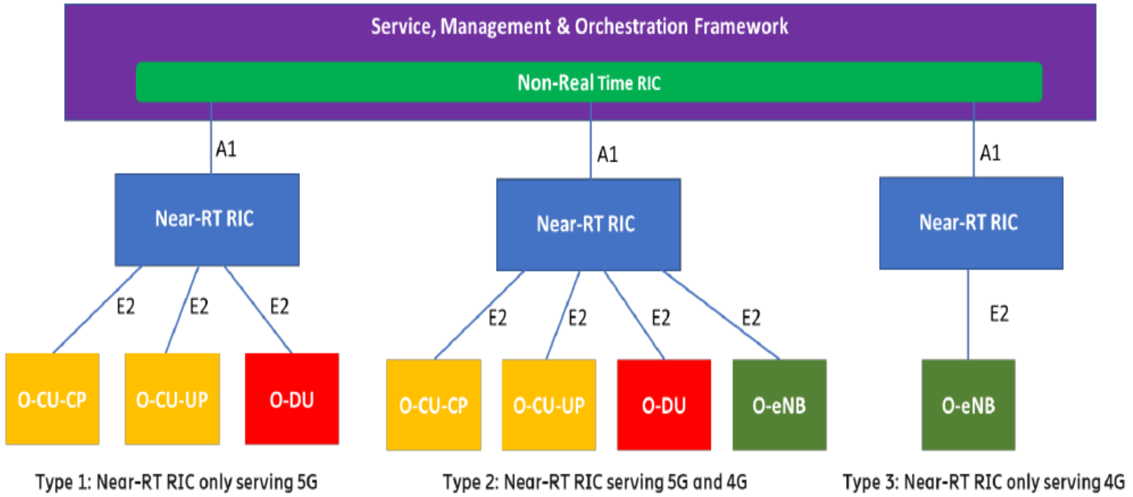

Figure Centralized Near-RT RIC Serving 4G and 5G Simultaneously

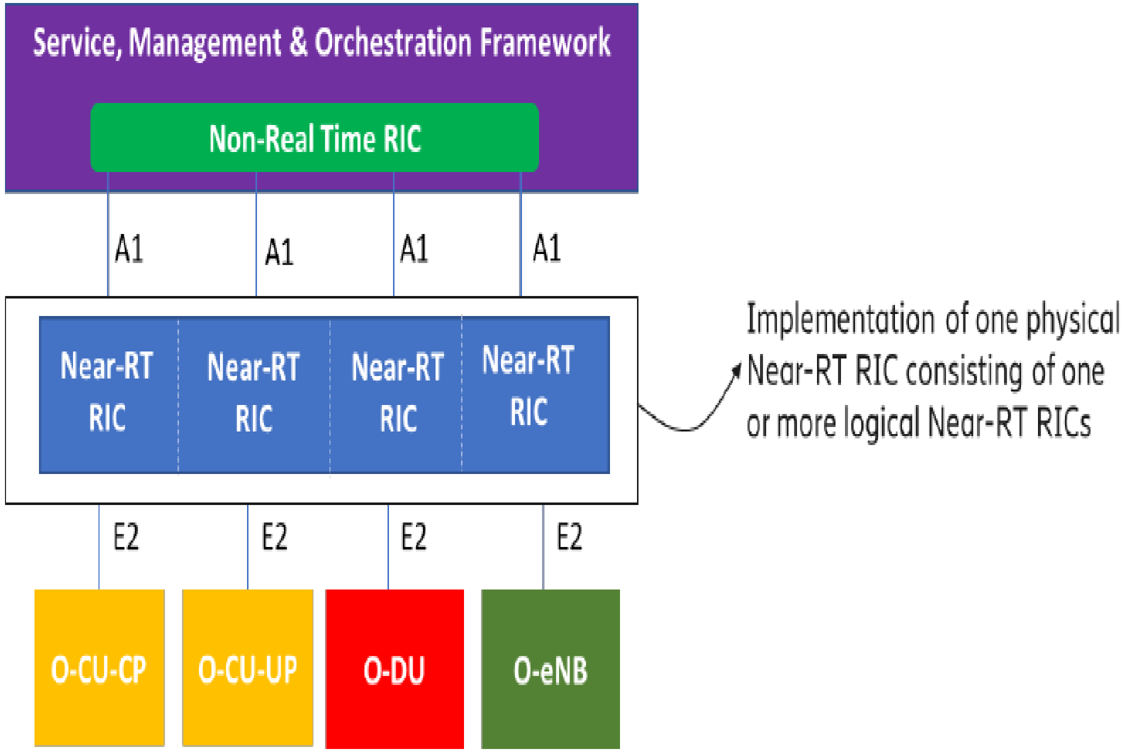

Figure : Distributed Near-RT RIC

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O-RAN.WG2.Use-Case-Requirements-v05.00
Technical Specification
O-RAN Working Group 2
Non-RT RIC & A1 Interface: Use Cases and Requirements

UE Identifier	UE Id=1, S-NSSAI =1	UE Id=2, S-NSSAI =2	UE Id=3, S-NSSAI =3
User Traffic	5QI=1: Voice 5QI=8: FTP, Email	5QI=1: Voice 5QI=8: Email 5QI=83: Advanced Driving	5QI=1: Voice 5QI=8: Progressive Video 5QI=8: File sharing
Mobility Pattern	Stationary	High mobility	Low Mobility

The UEs are in an area covered by three frequency bands identified by Cell A, Cell B and Cell C respectively. Cell A is the macro licensed cell with the best coverage. Cell B is the unlicensed cell with limited coverage and Cell C is a licensed cell with narrow bandwidth but provides greater coverage area than cell B.

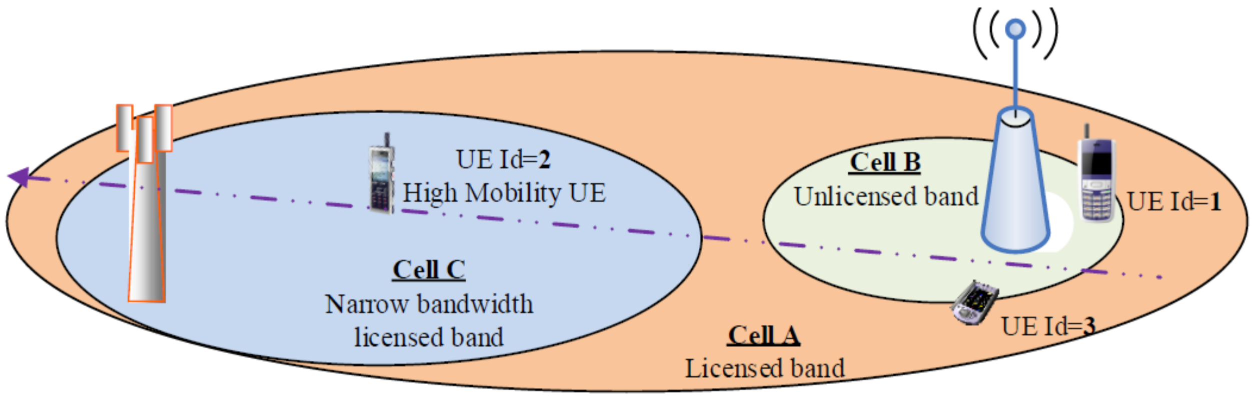


Figure : Cell layout for multi-access use case

Business Models
Adoption of Cloud-native Mechanism

1. Cloud Native Network Functions

The term "Cloud Native" originates from the ability to realise an **Economy at Scale – HyperScale** – through

- Agile Code Development and
- Code Integration Design Patterns.

At the Core is the idea to de-compose a Function into Microservices that can exist as Multiple Instances to allow to scale with demand.

Cloud-native is commonly agreed to **define Applications that follow the 12-Factor Methodology** (https://12factor.net/) as outlined by various **Market Leaders (as Microsoft & VMware** and summarised in Table 2 (next slide).

Thus, if VNFs follow the aforementioned 12-Factor Code Development and Integration Methodology, they can operate as Cloud Native Network Functions (CNFs).

Ref. NGMN Cloud Native Enabling Future Telco Platforms, May 2021

Cloud Native

Thus, if VNFs follow the aforementioned 12-Factor Code Development and Integration Methodology, they can operate as Cloud Native Network Functions (CNFs).

Table 2: 12-factor app properties

Number	Property	Description
1	Codebase	One codebase tracked in revision control and being able to deploy it into different production stages (development, staging, production).
2	Dependencies	Explicitly declare and isolate software dependencies through packaging.
3	Configuration	Software configuration stored in environment and not “hard coded” inside binary allowing different deployment scenarios.
4	Backing Services	Any service an individual function relies on must be treated as an attached (remote) service that can be reached over a network. Examples are databases or external service such as Twitter or Google Maps.
5	Build, release, run	Separation of software development into separate stages disallowing changes to code after build phase to enforce proper code integration workflows.
6	Processes	The application is decomposed into individual stateless processes that can be packaged as individual microservices.
7	Port binding	Mapping function from internal port to public port, e.g. public HTTP Port 80 is mapped inside instance to port 8080 where the function is listening.
8	Concurrency	Microservices of same type can be scaled out to meet demand.
9	Disposability	Maximise robustness of microservice with fast start-up and graceful shutdown.
10	Dev/prod parity	Keep development, staging, and production as similar as possible.
11	Logs	Treat logs generated by a microservice as event streams that can be analysed outside of the application.
12	Admin Processes	Run admin/management tasks as one-off processes such as database migration.

In addition to the 12 Factors, three (3) more have risen in the Cloud Community which are listed in Table 3.

Table 3: Additional three properties to the 12 factor app properties

Number	Property	Description
13	API First	Make everything a service. Assume your code will be consumed by a front-end client, gateway, or another service.
14	Telemetry	Ensuring that the microservice is designed to include the collection of monitoring, domain-specific, and health/system data as part of the logs.
15	Authentication/ Authorization	Implementation of identity across all microservices that form the application.

4.1.5 Cloud Native vs Cloudified Network Functions

Number	Property	Description
13	API First	Make everything a service. Assume your code will be consumed by a front-end client, gateway, or another service.
14	Telemetry	Ensuring that the microservice is designed to include the collection of monitoring, domain-specific, and health/system data as part of the logs.
15	Authentication/ Authorization	Implementation of identity across all microservices that form the application.

Table 3: Additional three properties to the 12 factor app properties

It becomes apparent that **VNFs implementing NFs such as:**

- **Firewalling,**
- **IP Address assignment or**
- **Switching & Routing**

might NOT be able to comply entirely with the 12-Factor Paradigm.

For instance, aiming at implementing a **3GPP SA2 Service Communication Proxy (SCP) as a CNF, a Component performing Proxy-like Routing tasks can be certainly de-composed into Micro Services based on their Workload type (e.g. Long-running Tasks versus Short Logical Operation to determine an outcome);**

However, by decomposing a NF into Microservices the newly created CNFs need to be addressable among each other based on Stateless protocols like HTTP.

The result is a typical "Chicken and the Egg" Problem!?!??!?!

4.1.5 Cloud Native vs Cloudified Network Functions

The result is a typical "Chicken and the Egg" Problem, as the CNFs were supposed to implement Service Routing, but relies on a Service Routing among them.

Other factors such as:

- Port Binding and
- Dev/Prod Parity

simply Do Not Apply to Functions that sit below the Transport Layer where Ports are exposed.

Furthermore, for Networking related Tasks (Routing, Firewalling, etc.) Packets from senders such as the UE that are supposed to be handled must be encapsulated in a Stateless Protocol to reach the next Microservice that forms the Networking Application.

Thus, not all VNFs can be ported to CNFs to enable an economy at scale.

In addition to the 12 Factors, three (3) more have risen in the Cloud Community which are listed in Table 3.

Table 3: Additional three properties to the 12 factor app properties

Number	Property	Description
13	API First	Make everything a service. Assume your code will be consumed by a front-end client, gateway, or another service.
14	Telemetry	Ensuring that the microservice is designed to include the collection of monitoring, domain-specific, and health/system data as part of the logs.
15	Authentication/ Authorization	Implementation of identity across all microservices that form the application.

Ref. NGMN Cloud Native Enabling Future Telco Platforms, May 2021

Cloud Native vs Cloudified Network Functions

Furthermore, for Networking related Tasks (Routing, Firewalling, etc.) Packets from senders such as the UE that are supposed to be handled must be encapsulated in a Stateless Protocol to reach the next Microservice that forms the Networking Application.

Thus, not all VNFs can be ported to CNFs to enable an economy at scale.

However, even though not all 12 Factors can be fulfilled for some VNF types, VNFs can be Cloudified aiming at a high adoption of the Cloud Native factors without the notion of de-composing a VNF into Microservices (CNFs) that form the Application.

Thus, (it is argued) for the introduction of the term "Cloudified VNF (cVNF)" indicating the adoption of the Cloud Native factors 1-5, 10 & 11.

Table 2: 12-factor app properties

Number	Property	Description
1	Codebase	One codebase tracked in revision control and being able to deploy it into different production stages (development, staging, production).
2	Dependencies	Explicitly declare and isolate software dependencies through packaging.
3	Configuration	Software configuration stored in environment and not "hard coded" inside binary allowing different deployment scenarios.
4	Backing Services	Any service an individual function relies on must be treated as an attached (remote) service that can be reached over a network. Examples are databases or external service such as Twitter or Google Maps.
5	Build, release, run	Separation of software development into separate stages disallowing changes to code after build phase to enforce proper code integration workflows.
6	Processes	The application is decomposed into individual stateless processes that can be packaged as individual microservices.
7	Port binding	Mapping function from internal port to public port, e.g. public HTTP Port 80 is mapped inside instance to port 8080 where the function is listening.
8	Concurrency	Microservices of same type can be scaled out to meet demand.
9	Disposability	Maximise robustness of microservice with fast start-up and graceful shutdown.
10	Dev/prod parity	Keep development, staging, and production as similar as possible.
11	Logs	Treat logs generated by a microservice as event streams that can be analysed outside of the application.
12	Admin Processes	Run admin/management tasks as one-off processes such as database migration.

Ref. NGMN Cloud Native Enabling Future Telco Platforms, May 2021

1. 3GPP 5G System Architecture Service Communication Proxy NF to NF Service Interaction

Annex E (informative):
Communication models for NF/NF services interaction

E.1 General

This annex provides a high level description of the different communication models that NF and NF Services can use to interact which each other.

Table E.1-1 summarizes the communication models, their usage and how they relate to the usage of an SCP.

Communication between Consumer and Producer	Service Discovery and Request Routing	Communication Model
Direct communication	No NRF or SCP; direct routing	A
	Discovery using NRF services; no SCP; direct routing	B
Indirect communication	Discovery using NRF services; selection for specific instance from the Set can be delegated to SCP. Routing via SCP	C
	Discovery and associated selection delegated to an SCP using discovery and selection parameters in service request; routing via SCP	D

Table E.1-1: Communication models for NF/NF services interaction summary

2. 5G UP GW SEPP and SeCoP - 2

Solution Key Issue #27: Policy based Authorization for Indirect Communication between Network Functions (NFs)

This solution addresses KI #22 - Authorization of NF Service Access in Indirect Communication.

The solution proposes Policy-based Authorization of NF Consumer requests in the **SeCoP (*Service Communication Proxy)*** associated with the NF Producer.

A Set of Policies are provisioned in the SeCoP which allow the SeCoP to recognise an incoming Service Request from a NF Consumer and determine whether to allow the request and set of services that can be allowed for the requesting NF.

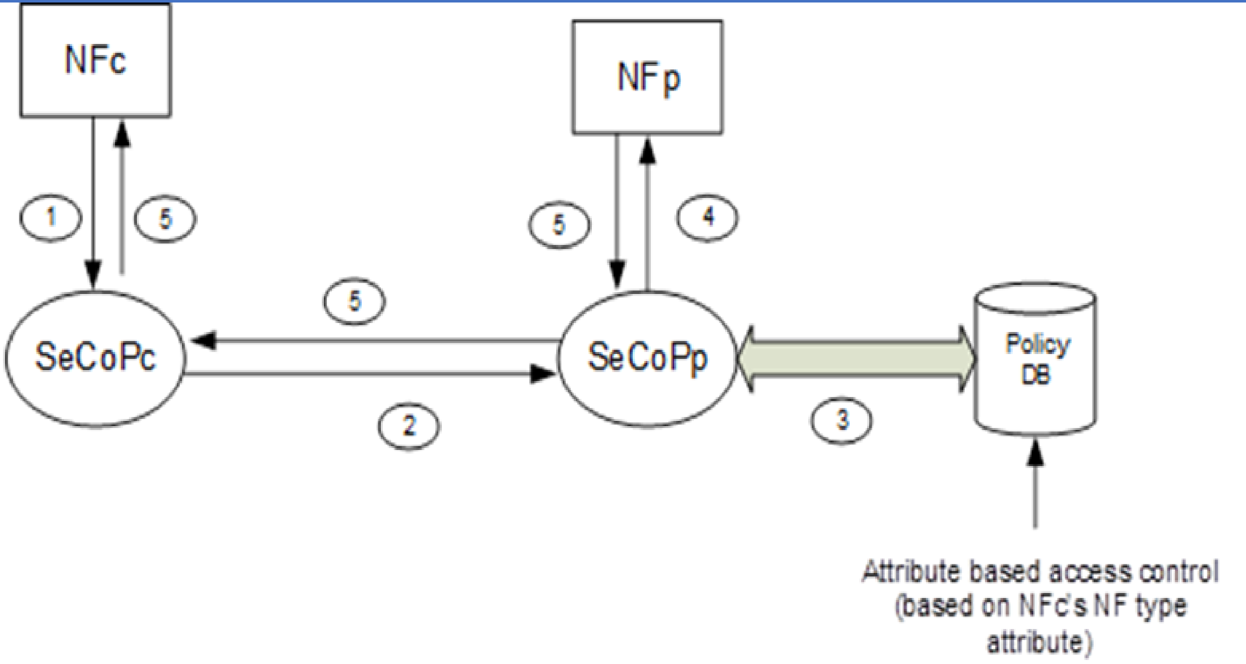


Fig.: Policy based Service Access authorization of NF consumer

Ref. 3GPP Security Aspects in 5G SBA, Rel. 16, Sept., 2020:

1. 3GPP 5G System Architecture Service Communication Proxy NF to NF Service Interaction

Model A - Direct communication without NRF interaction: Neither NRF nor SCP are used. Consumers are configured with producers' "NF profiles" and directly communicate with a producer of their choice.

Model B - Direct communication with NRF interaction: Consumers do discovery by querying the NRF. Based on the discovery result, the consumer does the selection. The consumer sends the request to the selected producer.

Model C - Indirect communication without delegated discovery: Consumers do discovery by querying the NRF. Based on discovery result, the consumer does the selection of an NF Set or a specific NF instance of NF set. The consumer sends the request to the SCP containing the address of the selected service producer pointing to a NF service instance or a set of NF service instances. In the latter case, the SCP selects an NF Service instance. If possible, the SCP interacts with NRF to get selection parameters such as location, capacity, etc. The SCP routes the request to the selected NF service producer instance.

Model D - Indirect communication with delegated discovery: Consumers do not do any discovery or selection. The consumer adds any necessary discovery and selection parameters required to find a suitable producer to the service request. The SCP uses the request address and the discovery and selection parameters in the request message to route the request to a suitable producer instance. The SCP can perform discovery with an NRF and obtain a discovery result.

Figure E.1-1 depicts the different communication models.

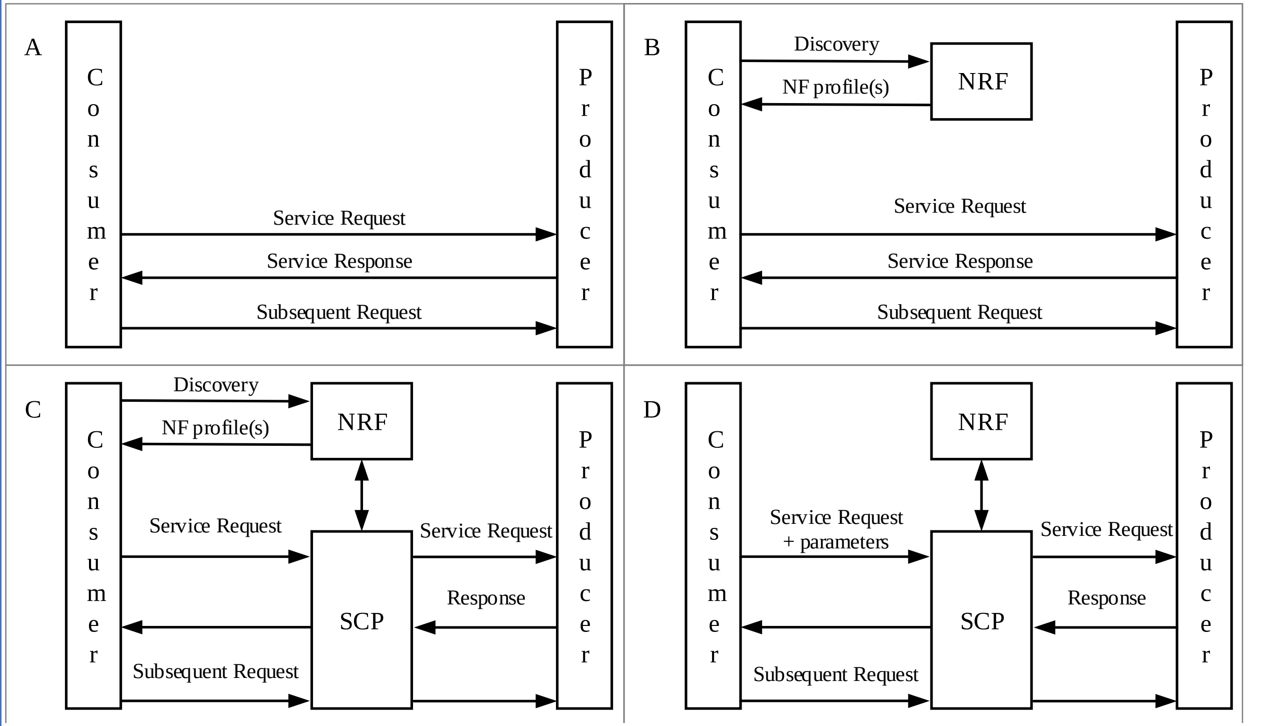


Figure E.1-1: Communication models for NF/NF services interaction

Ref. 3GPP TS 23 501 5G System Architecture Rel 17 March 2022

2. 5G UP GW SEPP (Secure Edge Protection Proxy) - 1

Solution #20: UP Gateway (GW) Function on the inter - PLMN N9 interface

This solution provides a solution for Key Issue #27.

The SEPP-U is a GW Function used for filtering **GTP-U** traffic on the N9 interface.

The SEPP-U filters GTP-U messages in a way that only genuine GTP-U packets, that correspond to active PDU sessions established through the N32 interface, can transit through the GW. All other GTP-U packets are discarded and logged. This ensures that no unwanted GTP-U packets enter or leave the Mobile Network.

The SEPP-U Function may be deployed either at the Edge of the Operator Network or collocated with the UPF. It monitors incoming/outgoing GTP-U traffic on the N9 Interface and executes GTP-U checks on every GTP-U packet on the N9 Interface.

SEPP-U interacts with SMF over the Nx Interface to obtain Local and Remote TunnelInfo Information **(TEID and tunnel IP address**).

SEPP-U operates as a transparent GW, which sits on the IP Route, examines each Packet and decides to either pass it or drop it.

In the following figure, SEPP-U is shown as a separate function in front of UPF to only forward GTP-U traffic, belonging to successfully established PDU sessions.

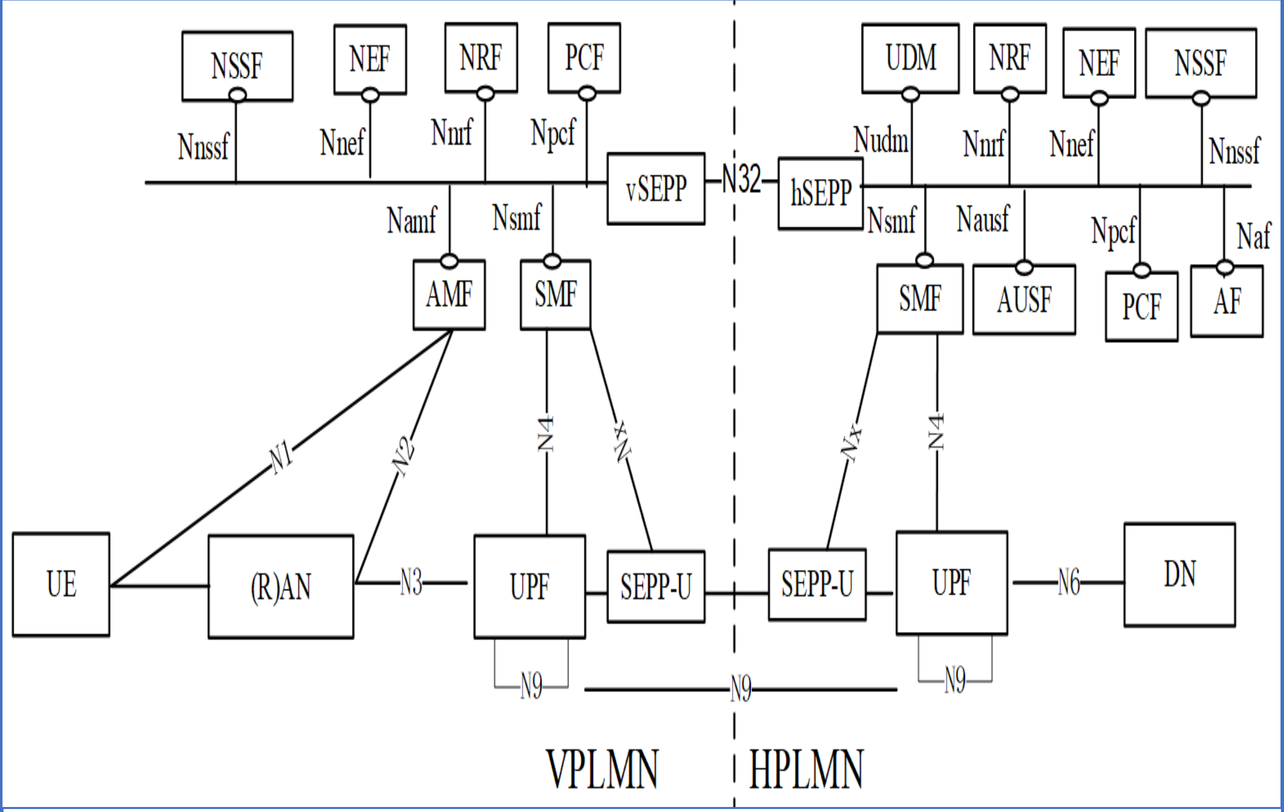


Fig.: UP GW Function SEPP (Secure Edge Protection Proxy) for the inter - PLMN N9 Interface

1. 3GPP 5G System Architecture Service Communication Proxy based on Service Mesh

G.2 An SCP based on service mesh

G.2.1 Introduction

This clause describes an SCP deployment based on a distributed model in which SCP endpoints are co-located with 5GC functionality (e.g. an NF, an NF Service, a subset thereof such as a microservice implementing part of an NF/NF service or a superset thereof such as a group of NFs, NF Services or microservices). This example makes no assumptions as to the internal composition of each 5GC functionality (e.g. whether they are internally composed of multiple elements or whether such internal elements communicate with means other than the service mesh depicted in this example).

In this deployment example, Service Agent(s) implementing necessary peripheral tasks (e.g. an SCP endpoint) are co-located with 5GC functionality, as depicted in Figure G.2.1-1.

In this example, **Service Agents and 5GC Functionality, although co-located, are separate components**.

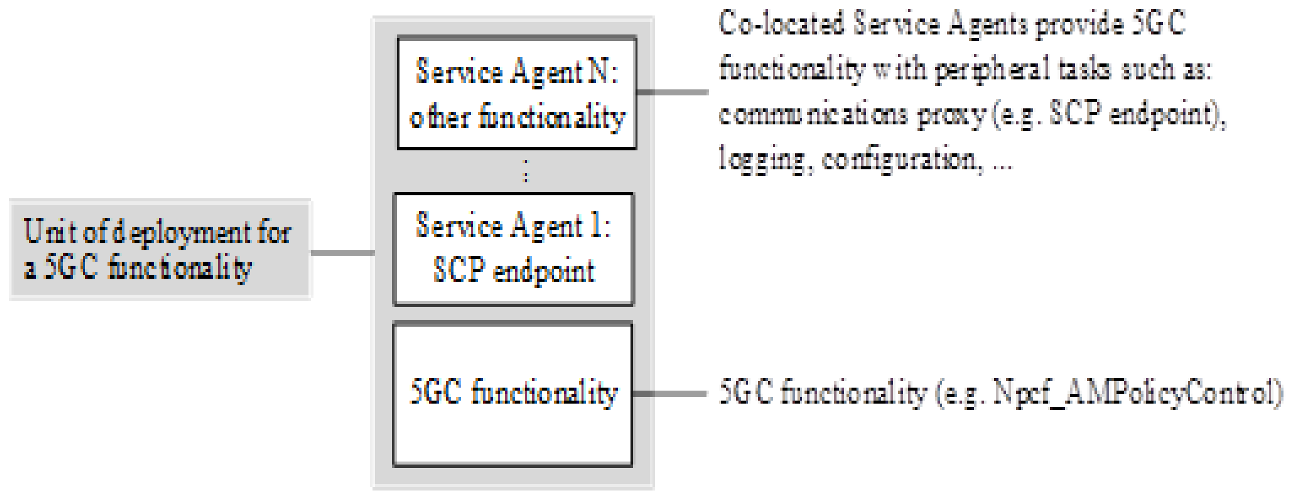


Fig. G.2.1-1: Deployment unit: 5GC Functionality & co-located Service Agent(s) implementing peripheral tasks

Ref. 3GPP TS 23 501 5G System Architecture Rel. 17 March 2022

1. 3GPP 5G System Architecture SCP based on Independant Deployment Units

G.3 An SCP based on Independent Deployment Units

For SBI-based Interactions (SBI) with other 5GC Functions, a Consumer communicates through a SCP Agent via SBI (1).

SCP Agent selects a target based on the Request and routes the Request to the target SCP Agent (2).

What Routing and Selection Policies each SCP Agent applies for a given request is determined by Routing and Selection Policies determined by the SCP Controller using for example information provided via NRF (3) or locally configured in the SCP Controller.

The Routing and Selection Information is provided by the SCP Controller to the SCP Agents via SCP Internal Interface (4).

Direct communication can co-exist in the same deployment based on 3GPP specified mechanisms.

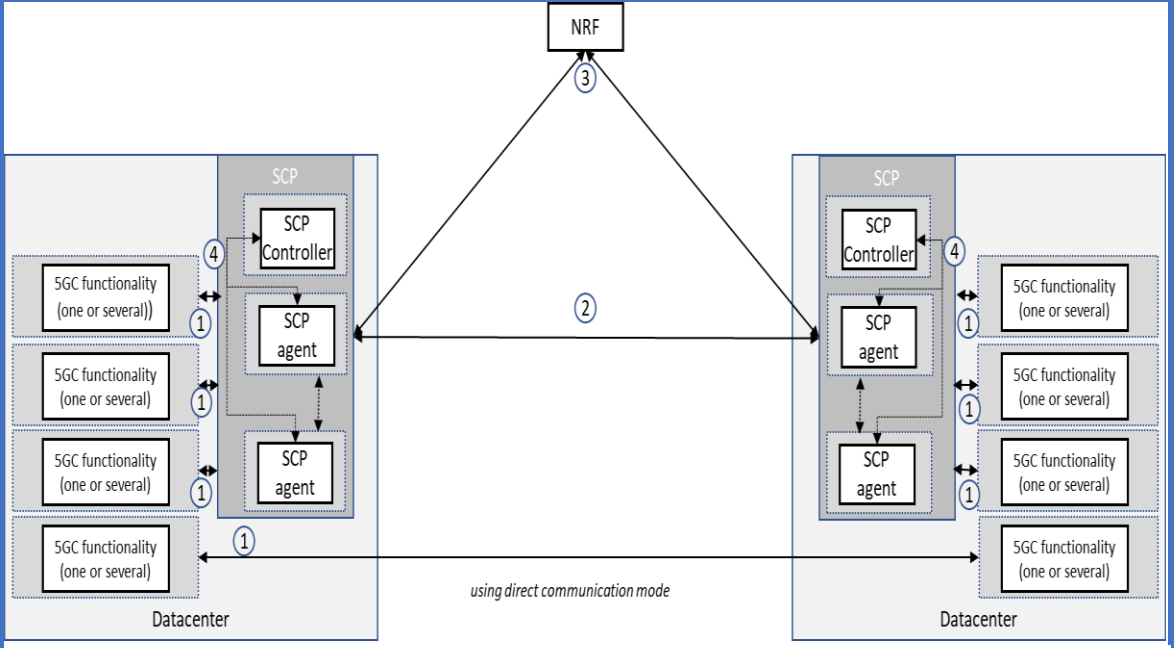


Figure G.3-3: Overview of SCP deployment

G.4 An SCP deployment example based on Name-based Routing

G.4.0 General Information

SCP based on a Name-based Routing Mechanism that provides
IP over ICN Capabilities such as those described in Xylomenos, George, et al.: "IP over ICN goes live", 2018 European Conference on Networks & Communications (EuCNC). IEEE, 2018.

SCP offering based on an SBA-platform to interconnect 5GC Services (or a subset of the respective services).

The Name-based Routing mechanism, described in this deployment example, is realized through a Path Computation Element which is the Core part of the SCP.

The 5GC Services are running as Microservices on Cloud/ deployment Units (Clusters).

A Service Router is the Communication Node (Access Node/GW) between the SCP and the 5GC Services and resides as a single unit within a Service Deployment Cluster.

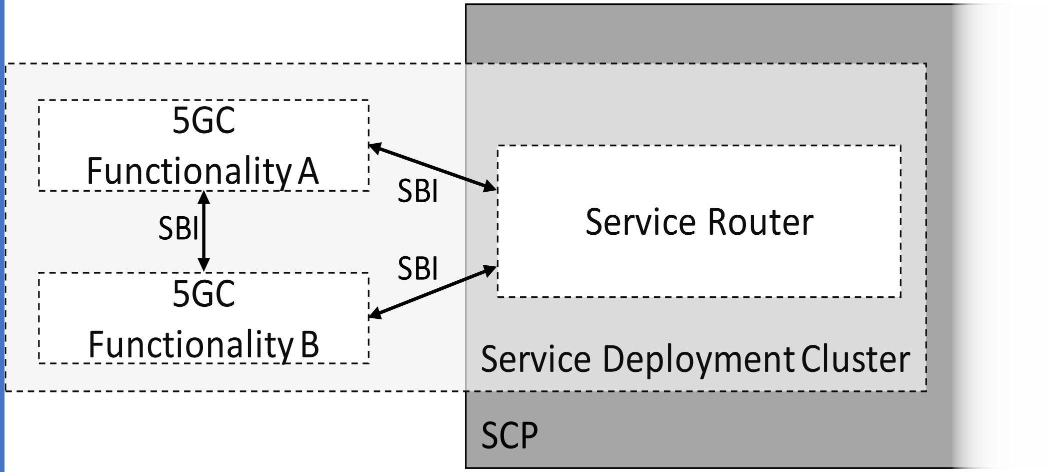
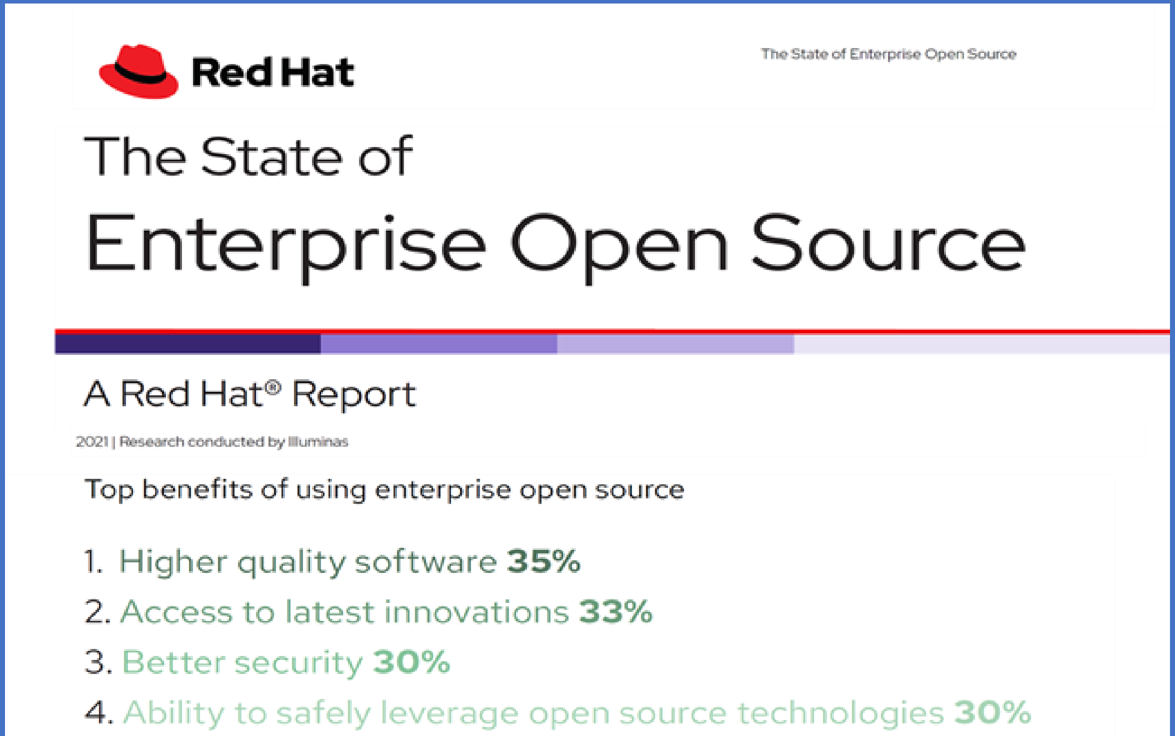


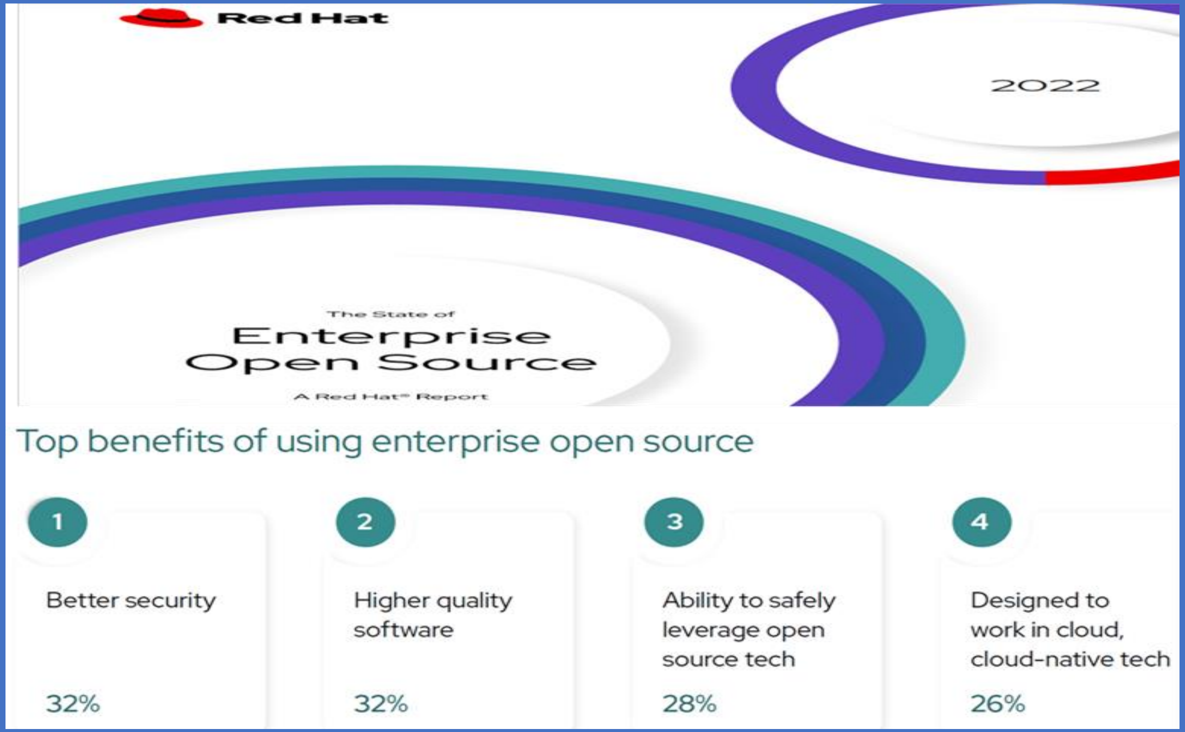
Fig. G.4-1: Deployment unit: 5GC Functionality and Co-located Service Agent(s) implementing peripheral tasks

Ref. 3GPP TS 23 501 5G System Architecture Rel. 17 June 2021: 487

Business

The findings in the Red Hat's *The State of Enterprise Open-Source* reports from 2021 and 2022 (see below) indicating the importance of Open Source lower TCO (Total Cost of Ownership) shift to drop down to 6th place (from top position indicated 2 years ago (2019) and preference, choice and assigned priority by Enterprises to select an Open -source Project due to the following top 3 (three) benefits of using an Open Source Project, namely:





Enterprise open source for innovation

Consider the following findings from our survey:

Two years ago, lower cost of ownership was cited as the top benefit of enterprise open source. This year it's fallen to the sixth spot, well below "access to the latest innovations" in second. This year, 82% of IT leaders also agreed with the statement that "enterprise open source is used by the most innovative companies." About the same number, 81%, said that it "provides flexibility to customize solutions to meet company needs."

We see specific examples of enterprise open source adoption in emerging technology areas. 79% of respondents expect that over the next two years, their organization will increase use of enterprise open source software for emerging technologies. In the two most prevalent emerging tech areas, edge computing/IoT and artificial intelligence/machine learning (AI/ML), use of enterprise open source is expected to significantly outpace proprietary software over the same period. In edge computing/IoT, enterprise open source is expected to increase from 55% of cases to 72% two years from now. And, for AI/ML, our survey found that proprietary software use is actually expected to decrease, while enterprise open source use shoots up from 48% to 65%.

The benefits are broad and strategic

When we began running this survey four years ago, the top benefit of enterprise open source was clear: lower total cost of ownership (TCO). This result was likely a surprise to no one. Linux, along with enterprise open source more generally, was adopted by companies in no small part because it was a less expensive alternative to proprietary UNIX and proprietary networking-related applications. Even if this view of enterprise open source began to increasingly diverge from reality, it remained a stereotype. However, we have seen a steady shift away from enterprise open source being defined as cheaper software rather than better software. Of course, this is not to say that enterprise open source can't be less expensive to acquire and operate than proprietary software. But price is not how IT leaders generally frame their thinking about enterprise open source today.

This year's top two benefits? Better security and higher quality software. By contrast, lower TCO has declined dramatically in importance. It is now near the bottom of the benefits list in ninth place.

Red Hat

The State of Enterprise Open Source

The State of Enterprise Open Source

A Red Hat® Report

2021 | Research conducted by Illuminas

Top benefits of using enterprise open source

1. Higher quality software **35%**
2. Access to latest innovations **33%**
3. Better security **30%**
4. Ability to safely leverage open source technologies **30%**

Red Hat

2022

The State of Enterprise Open Source

A Red Hat® Report

Top benefits of using enterprise open source

1	2	3	4
Better security	Higher quality software	Ability to safely leverage open source tech	Designed to work in cloud, cloud-native tech
32%	32%	28%	26%

5G Architecture for Hybrid and Multi-Cloud Environments

A Unified Approach to Developing, Deploying & Operating 5G Services - including 5G RAN, Core, OSS & BSS Applications – in Public & Private Cloud Environments is a Key Enabler for Communication Service Providers (CSPs) to successfully adopt a Hybrid & Multi-Cloud Strategy. The "main benefits" are "Faster Time to Market" (TTM) & "Lower Total Cost of Ownership" (TCO). As *Figure 2* illustrates, this approach could *lead to a lot of Diversity & Heterogeneity in the Deployment Targets for Network SW* Vendors. Designing & Operating an Application that is capable of utilizing such a Diverse Set of HCP Managed Services also creates *Several Challenges for Network SW* Vendors & CSPs alike. **The Main Challenges to overcome in a Hybrid & Multi-Cloud Strategy** are: *1. Maintaining Portability; 2. Controlling the Total Cost of Ownership (TCO); 3. Optimizing Productivity & Time to Market (TTM).* **DevOps** – *a Set of Practices* that brings together *SW Development & IT operations* with the **Goal of Shortening the Development & Delivery Cycle & increasing SW Quality - is often thought of and discussed in the Context of a Single Company or Organization.** The Company usually Develops the SW, Operates it & Provides it as a Service to Customers, according to the SW-as-a-Service (SaaS) Model. **Within this context**, it is easier to have **Full Control over the Entire Flow**, including **Full Knowledge of the Target Deployment Environment.** In the **Telecom Space**, by contrast, we typically follow the **"as-a-Product (aaP) Business model**, in which **SW is developed by Network SW Vendors** such as Ericsson (Nokia, Huawei, ZTE) & provided to Communication Service Providers (CSPs) that Deploy & Operate it within their Network. This **Business Model requires the consideration of additional aspects**. As shown in *Figure 1*, **the most important contrasts between the Standard DevOps SaaS Model & the Telecom aaP Model** are the **Multiplicity of Deployment Environments & the fact the Network SW Vendor Development Teams cannot know upfront exactly what the Target Environment looks like**. Although a SaaS Company is likely to Deploy & Manage its SW on two (2) or more different Cloud Environments, this is inevitable within Telco, as each CSP creates &/or selects its own Cloud infrastructure.

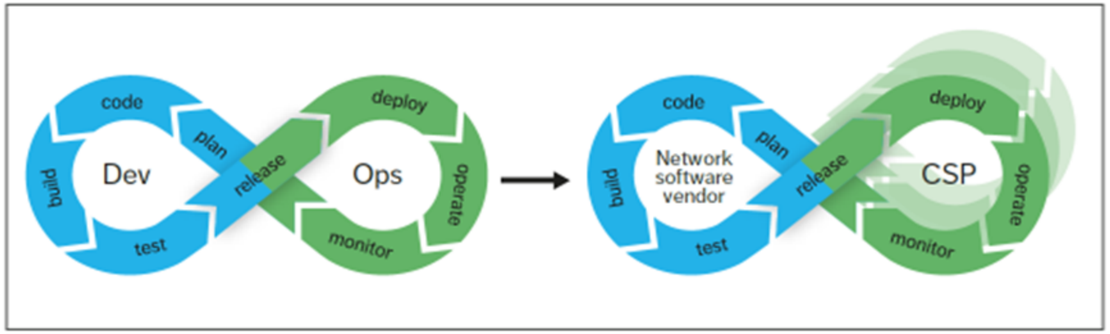


Figure 1: The DevOps and (Telecom) aaP Business Models

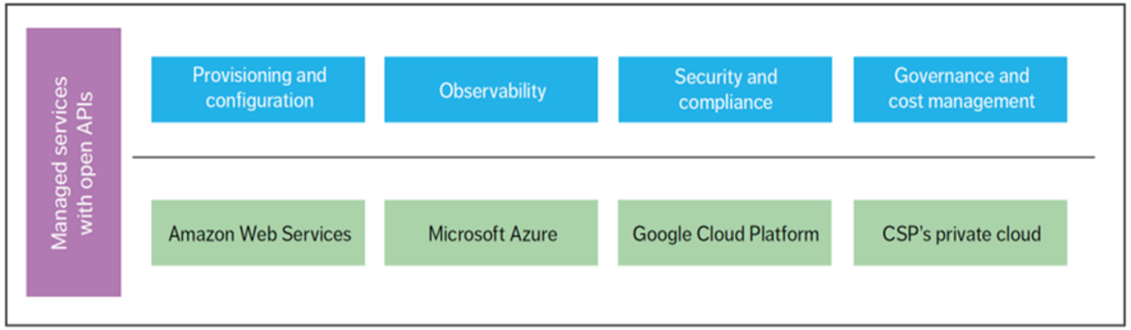


Figure 3: Key Enablers for a Multi-Cloud Native Application

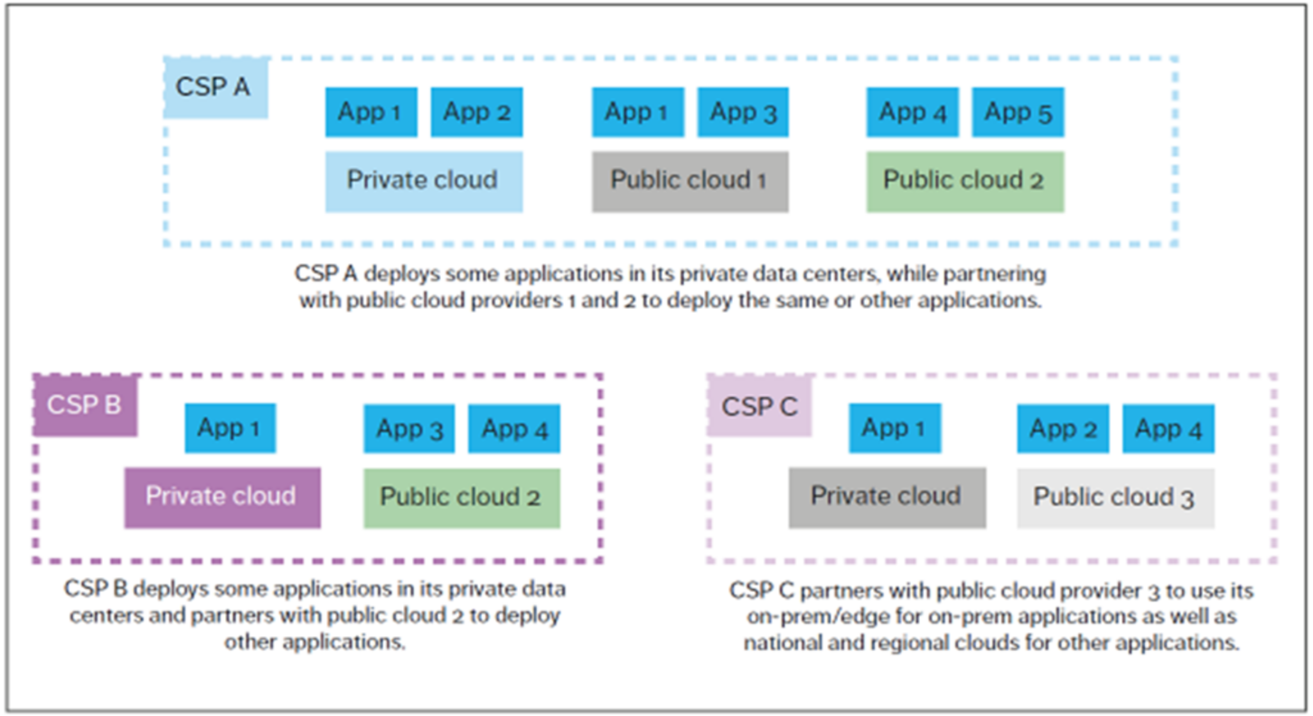


Figure 2: Examples of Hybrid and Multi-Cloud Deployment Scenarios that Applications must be able to support

In addition to hypervisor-based execution environments that offer hardware abstraction and thread emulation services, the OS container execution environment provides kernel services as well. Kernel services include:

- Process control.

EXAMPLE 1: OS process creation; scheduling; wait and signal events; termination.

- Memory management.

EXAMPLE 2: Allocation and release of regular and large pages; handling memory-mapped objects and shared memory objects.

- File system management.

- File management.

EXAMPLE 3: Creation, removal, open, close, read and write file objects.

- Device management.

EXAMPLE 4: Request, release, configuration and access.

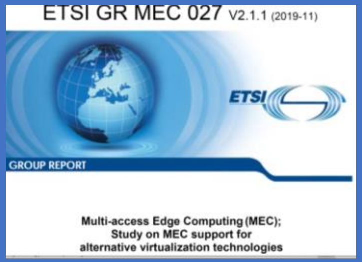
- Communication services.

EXAMPLE 5: Protocol stack services, channel establishment and release, PDU transmission and reception.

- System information maintenance.

EXAMPLE 6: Time and date, system and OS resource data, performance and fault indicators.

The OS container-to-VNFC logical interface is typically realized via:



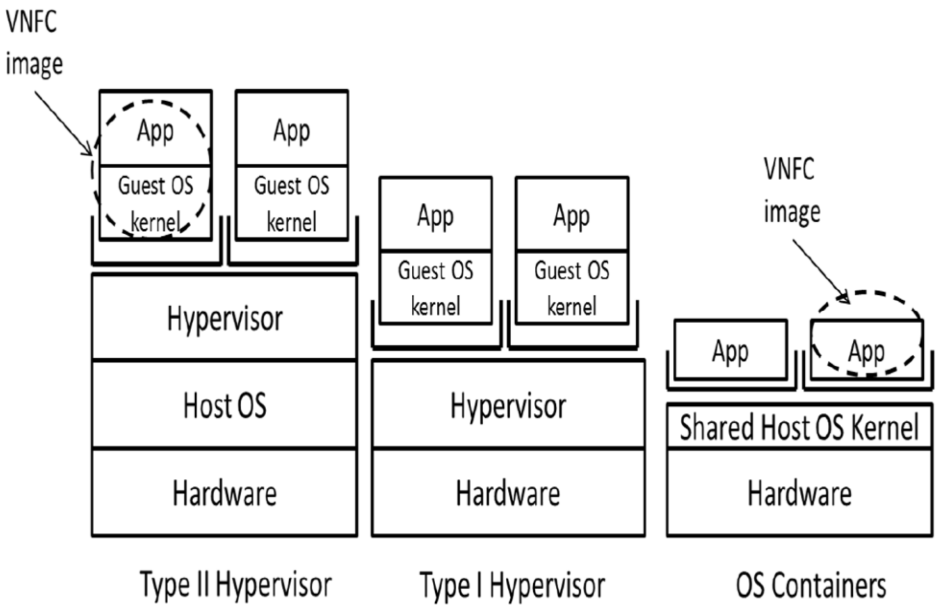
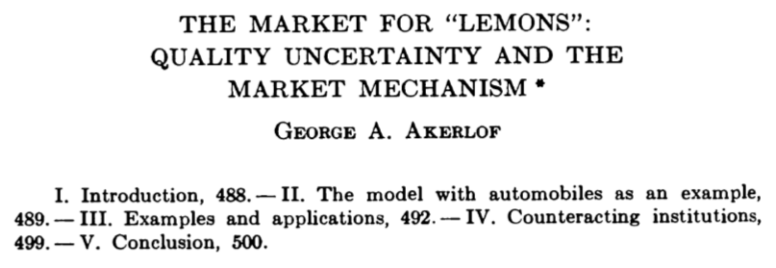
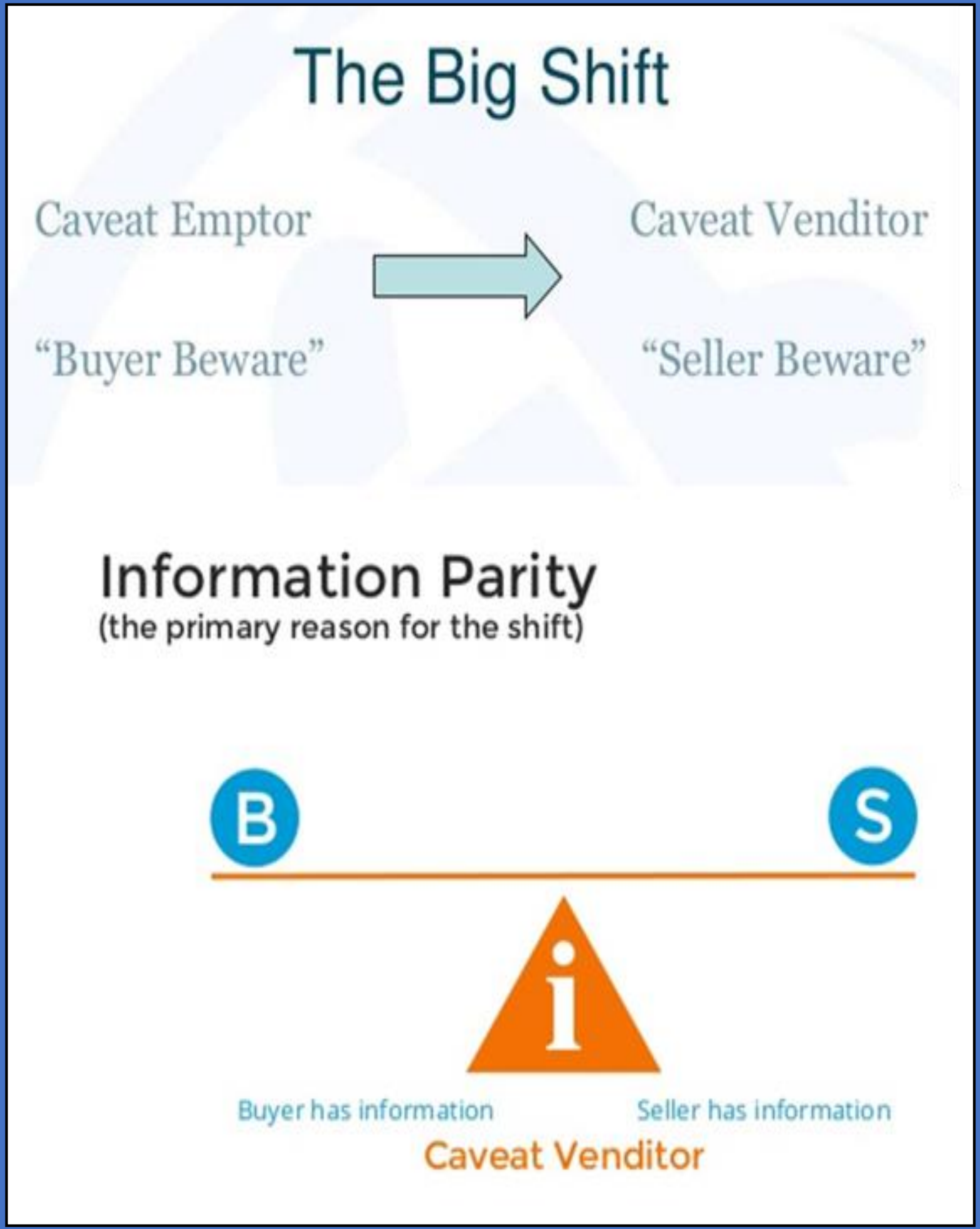


Figure 1: Hypervisor vs. OS Container solutions


THE MARKET FOR "LEMONS": QUALITY UNCERTAINTY AND THE MARKET MECHANISM *

GEORGE A. AKERLOF

I. Introduction, 488. — II. The model with automobiles as an example, 489. — III. Examples and applications, 492. — IV. Counteracting institutions, 499. — V. Conclusion, 500.



When Information is Ubiquitous:

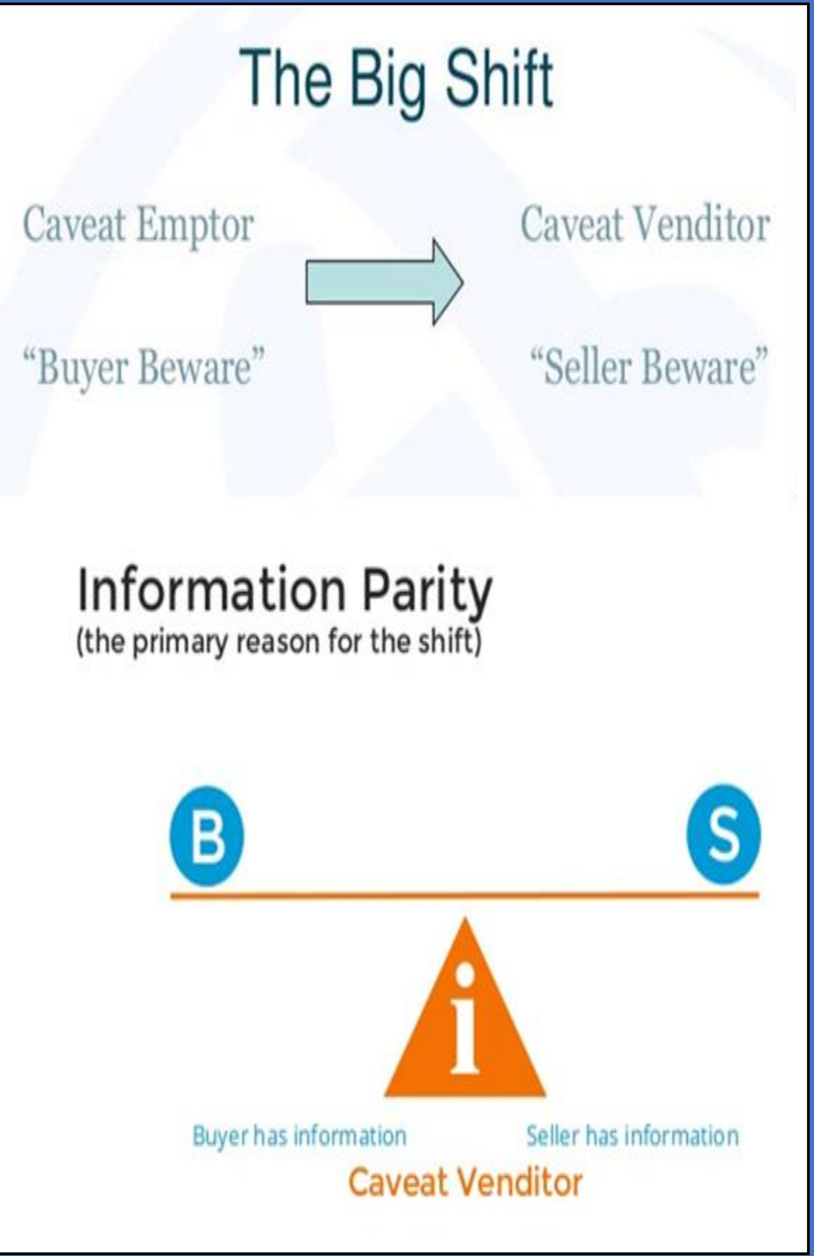
shift from **Information Inequality** to **Information Paritiy**

No longer enough

just to be able to Answer to Questions on Product/Solution/ Services

and/or present Platforms, Solutions, Services, Standards ...

Ref.: D.Pink, 2012



When Information is Ubiquitous

The Value of undertaking the role of "Unbiased Business Partner"

Shift in assigned importance **from "Problem - Solving" to**

"Problem-Identification/ Finding"

Ask the "Right Questions"
- to Identify Current Issues/Problems, curate the Vast Amount of Information &

- Ability to Hypothesize/Clarify on Future Problems, Inter-Dependencies

- Outline Future Multi-Vendor Inter- Operability & Scalability

- Ground for Personalized, Business Model and Agile Service Deployment.

Ref.: D.Pink, D-ve, 2012

Remarks & Questions?