5G PNI NPN/SNPN

"5G Private Networks"

Ike Alisson

LF Edge Akraino TSC member &

Akraino Documentation Sub-committee TSC Chair

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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)*

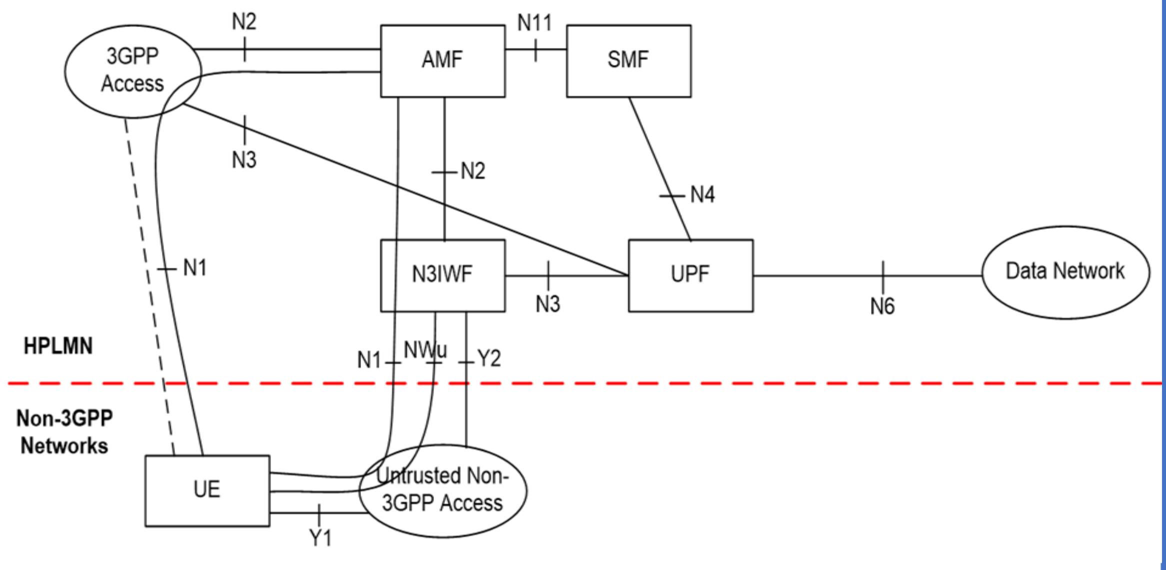

Fig. 1-1 Non-Roaming Architecture for 5G Core Network with Untrusted Non-3GPP Access

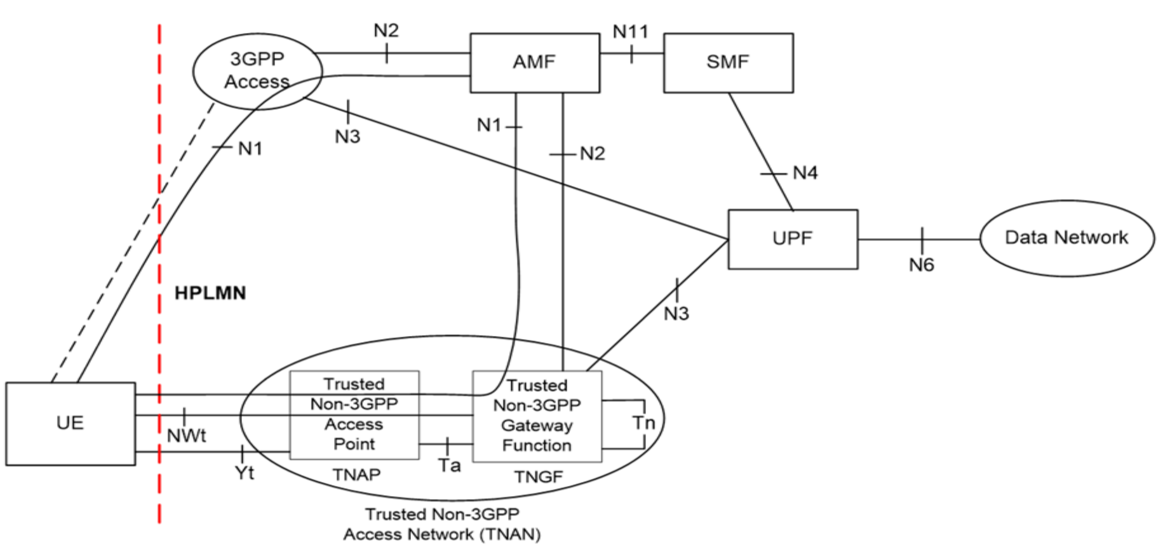

Fig. 1-2 Non-Roaming Architecture for 5G Core Network with Trusted Non-3GPP Access

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.

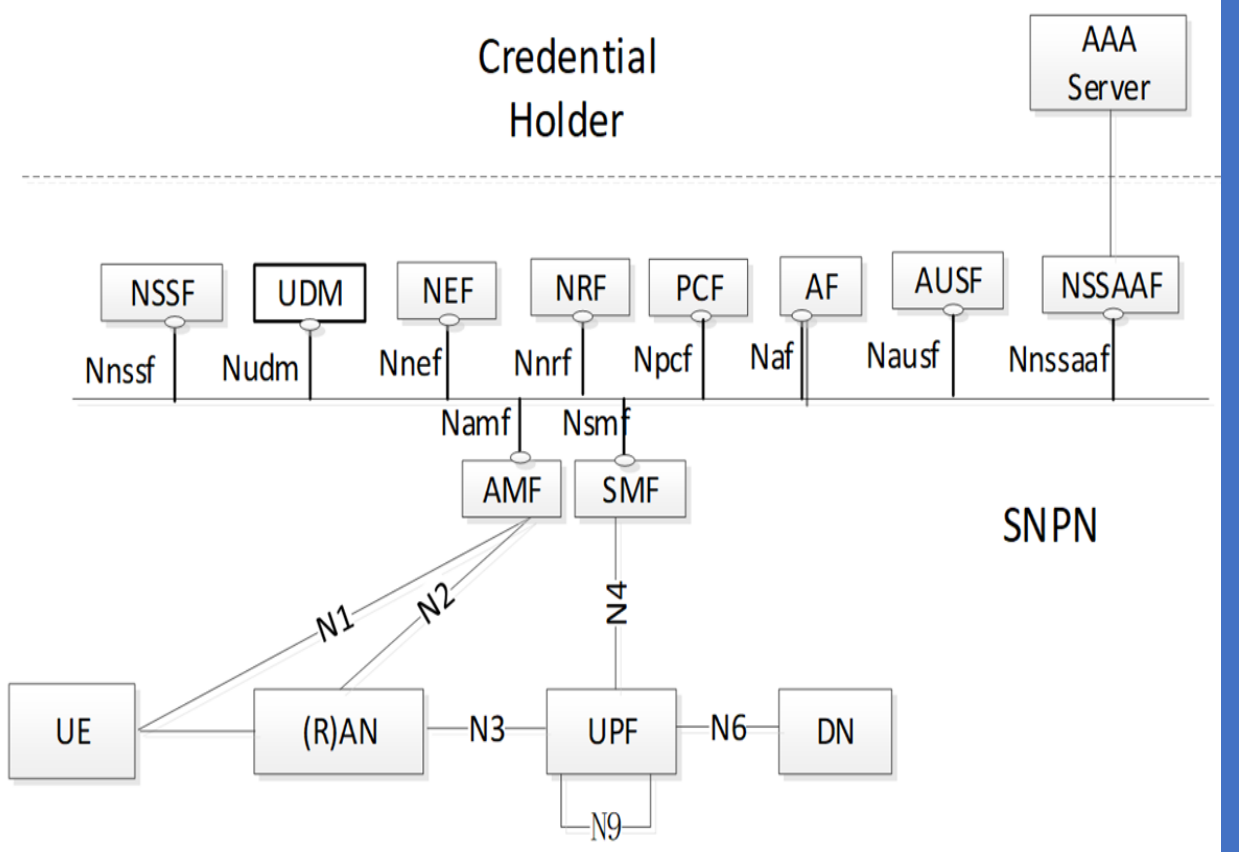

Fig. 2-1 5G System Architecture with Access to SNPN using credentials from Credentials Holder using AAA Server

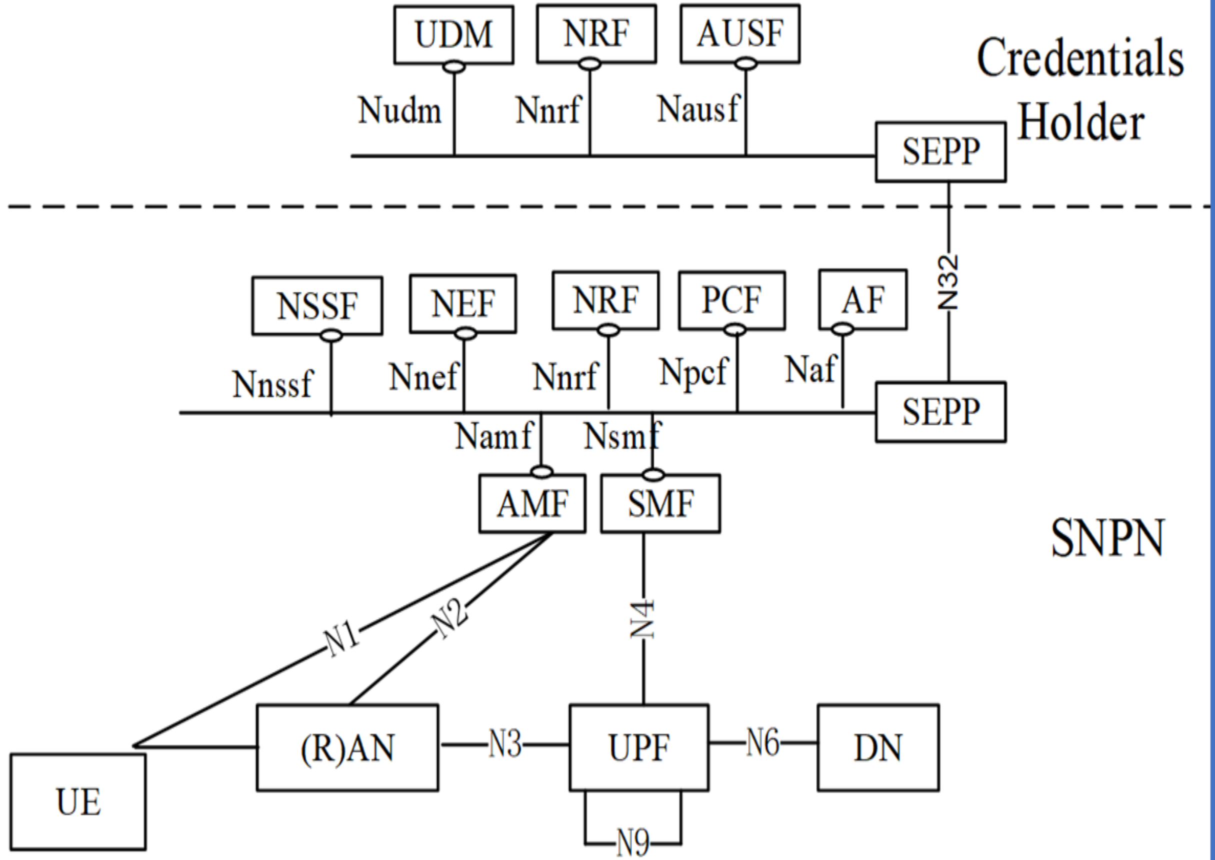

Fig. 3-1 5G System Architecture with Access to SNPN using credentials from Credentials Holder using AUSF and UDM

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.

NOTE 2: Which legal entities manage the number space is beyond the scope of this specification.

NOTE 3: The use of SNPN with self-assignment model NID such that the combination of PLMN ID and NID is not globally unique is not assumed for the Architecture described in Figure 5.30.2.9.3-1, Figure 5.30.2.9.2-1. and for SNPN - SNPN Mobility as described in clause 5.30.2.11.

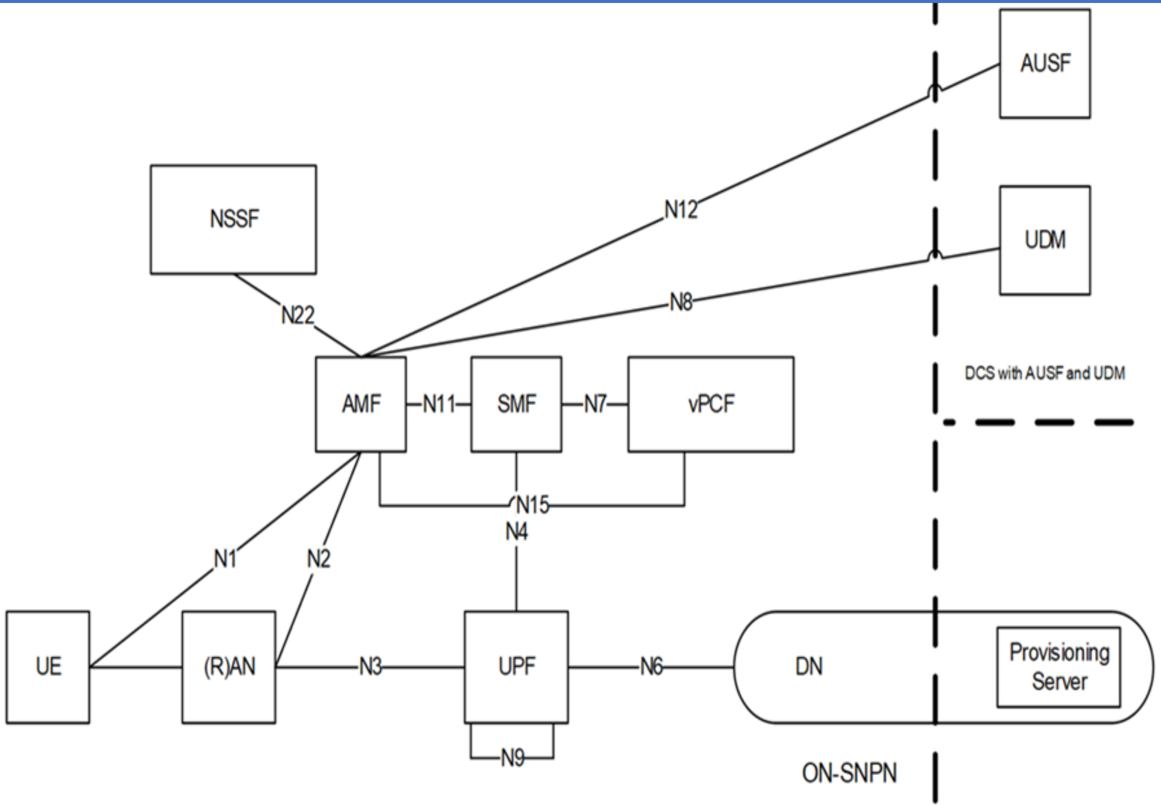

Fig.: Architecture for UE Onboarding in ON-SNPN when DCS includes AUSF and a UDM

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.

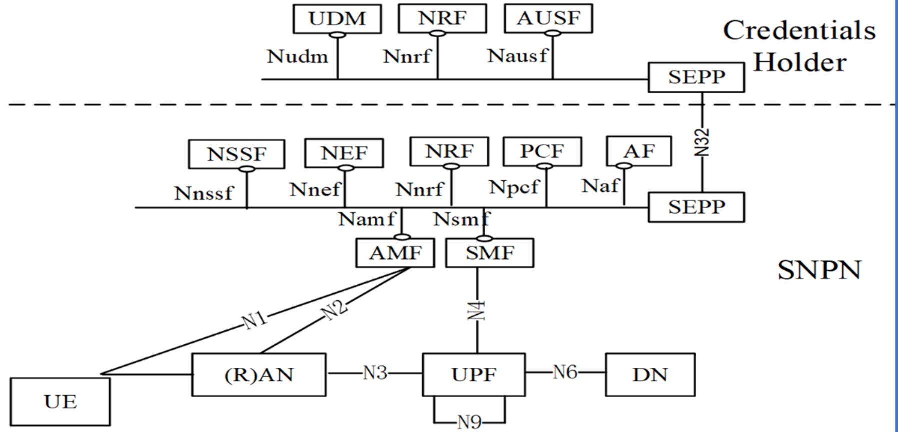

Fig. 3-1 5G System Architecture with Access to SNPN using credentials from Credentials Holder using AUSF and UDM

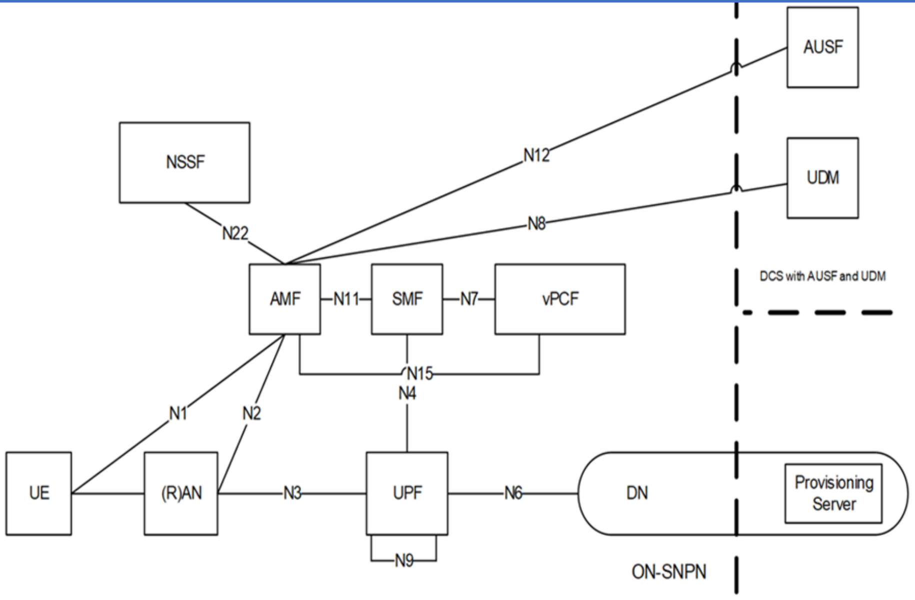

Fig.: Architecture for UE Onboarding in ON-SNPN when DCS includes AUSF and a UDM

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

	Key Issues					
Nr Solutions	#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				
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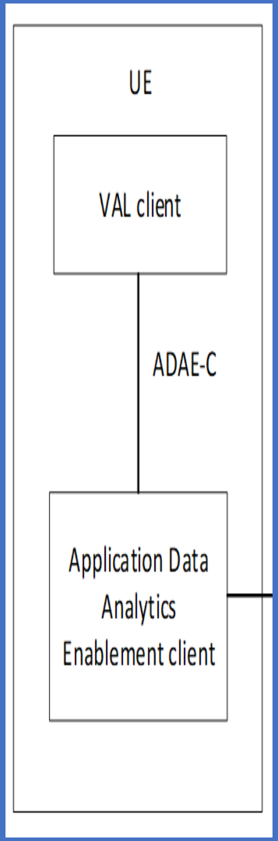
53			X			
54			X			
55		X				
56			X			

Ref.: 3GPP, Rel. 17

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



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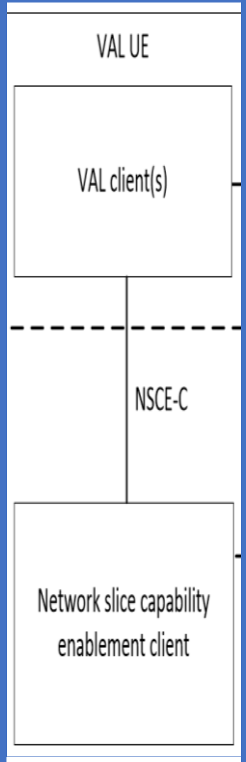

Fig.: NSCE-C

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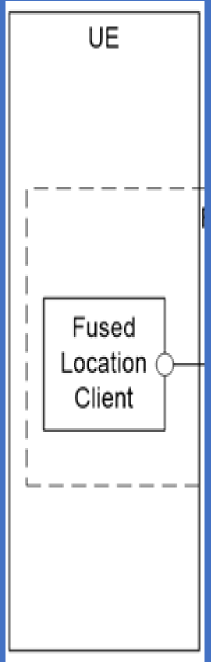

Fig. FLC Funct. In the UE

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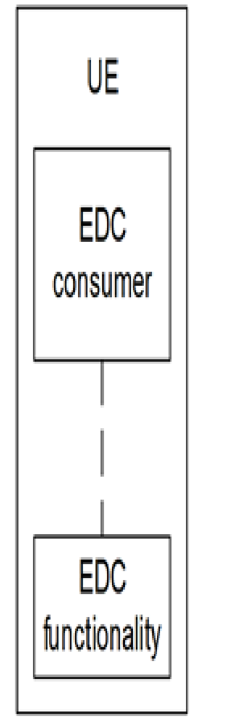

Fig. EDC Funct. in the UE

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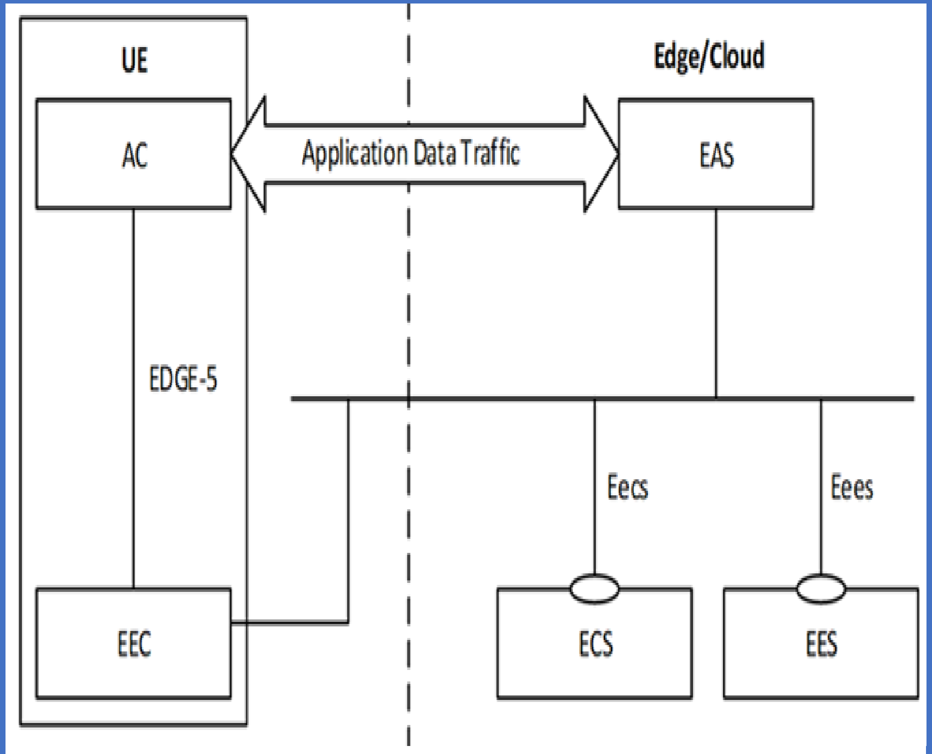


Fig. Archit. For Enabling Edge Applic. - Service-based Represent

Ref.: 3GPP, Rel. 17 & 18

5G ACT & ACR (Application Context Transfer & Application Context Relocation for Service Continutiy T-EAS & S-EAS

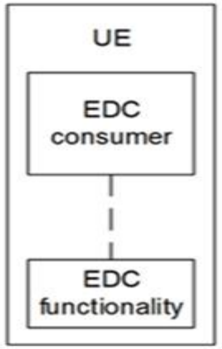


Fig. EDC Funct. in the UE

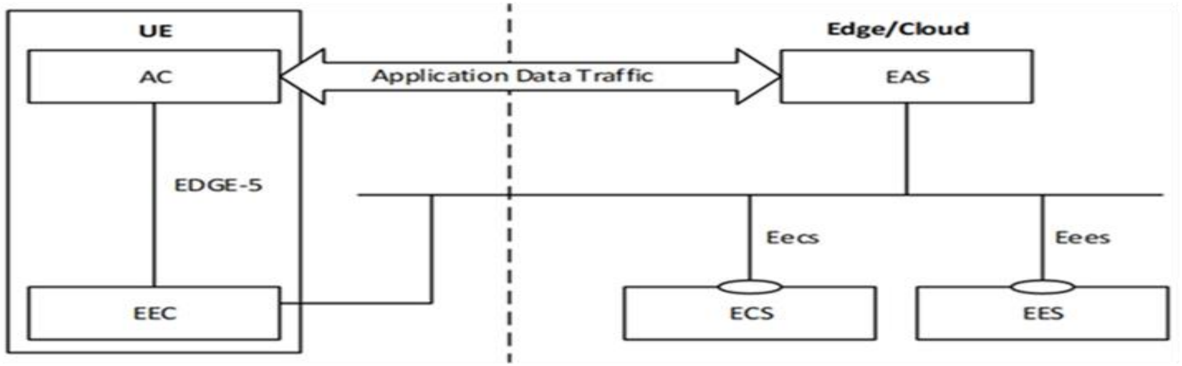


Fig. Archit. For Enabling Edge Applic. - Service-based Represent

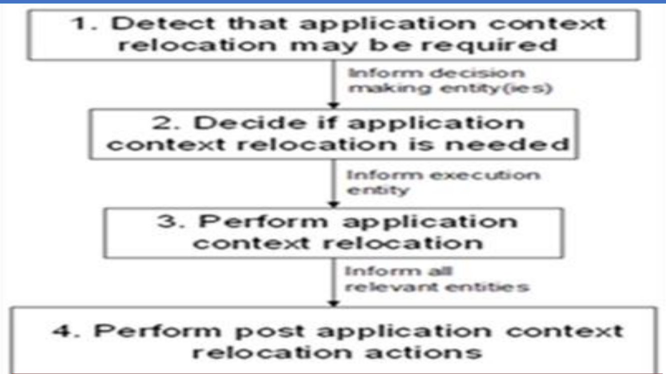


Fig. High level overview of ACR (Application Context Relocation)

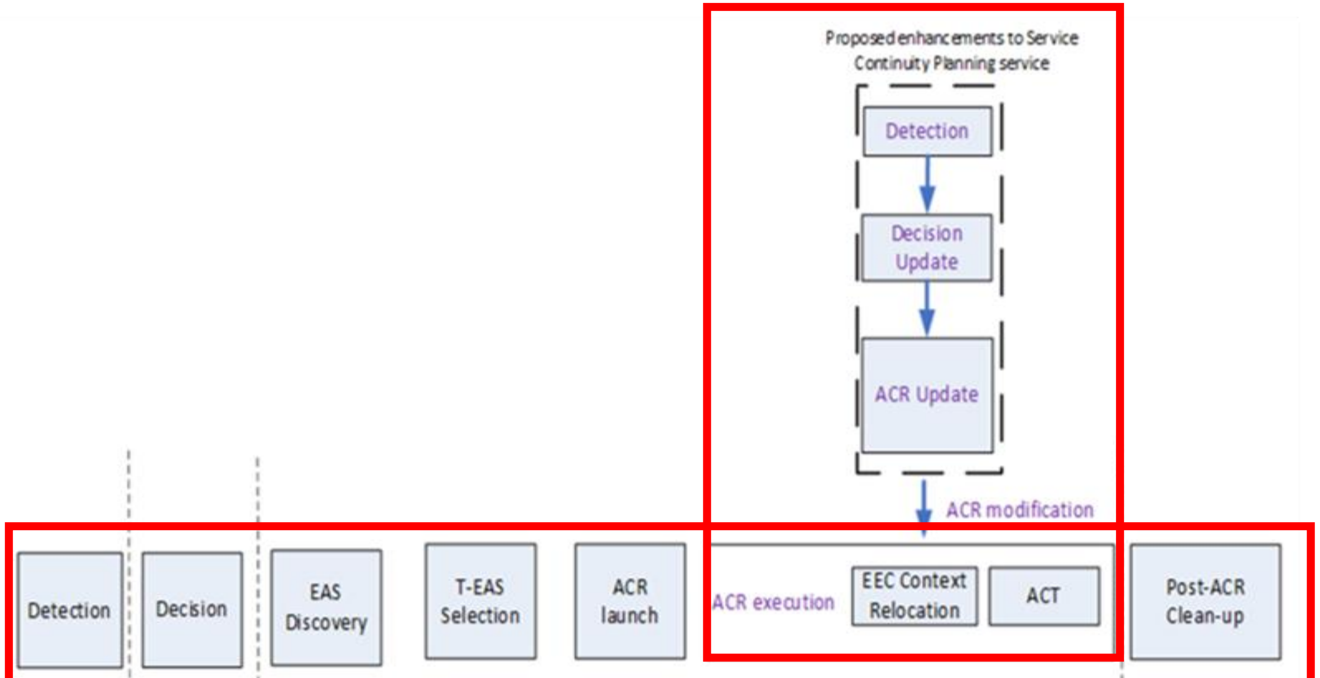


Fig. High-level of proposed ACR update in Service Continuity Planning Enhancement

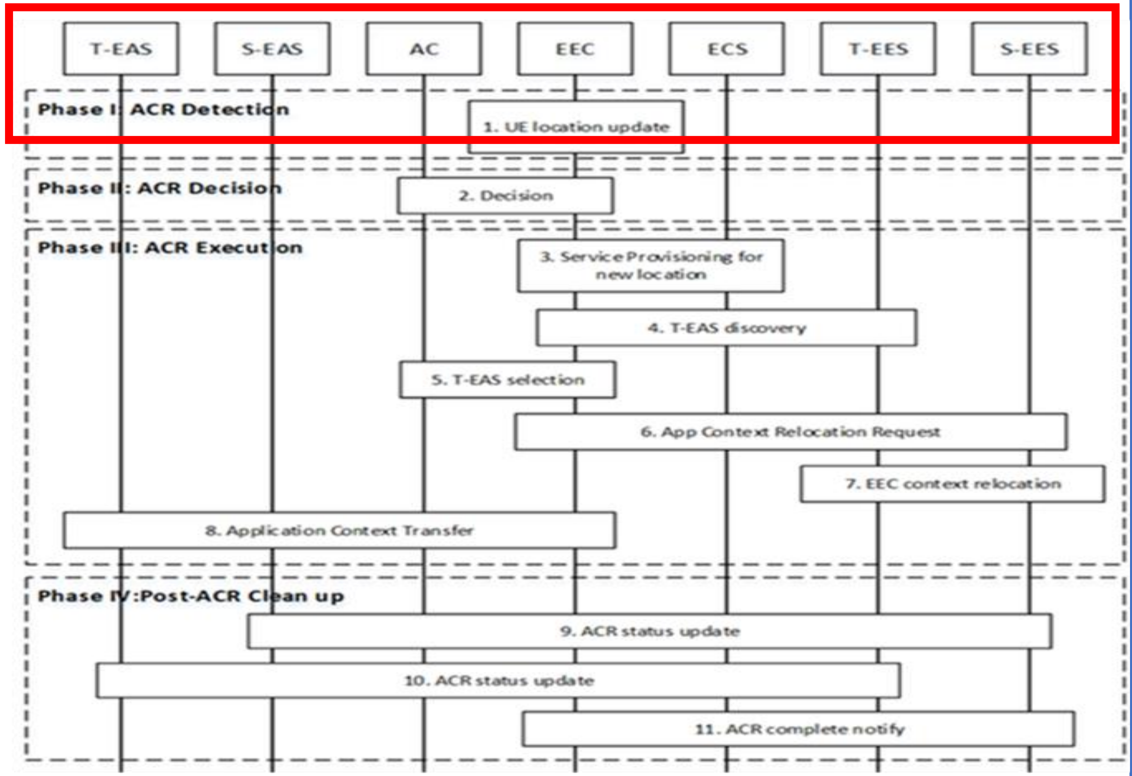


Fig. ACR initiated by the EEC & AC

2. Market Definition and Deployments of "Private 5G" PNI - NPN/NSPN - 1

2.1 <u>The Demand for Private Mobile Networks</u> based on 4G LTE (and increasingly 5G) Technologies is being driven by:

- The spiralling **Data,**
- **Security,**
- **Digitisation** and
- **Enterprise Mobility Requirements** of modern Business and Government entities.

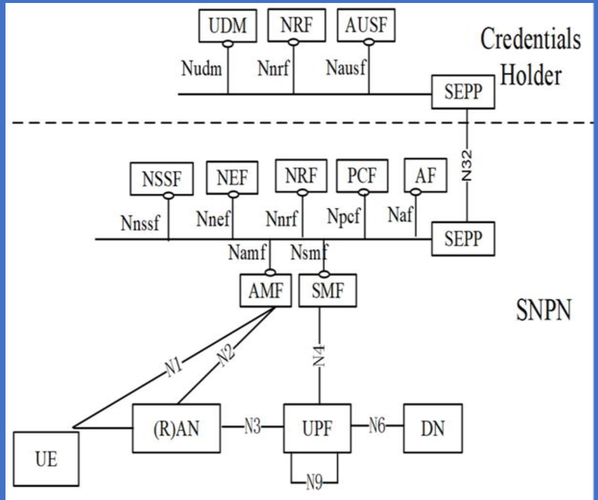


Fig. 3-1 5G System Architecture with Access to SNPN using credentials from Credentials Holder using AUSF and UDM

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

***2.2 <u>The Definition of a Private Mobile Network</u> ****used in this report is a 3GPP-based 4G LTE or 5G Network intended for the sole use of Private Entities, such as Enterprises, Industries & Governments*

The definition includes Multe-Fire or Future Railway Mobile Communication System. The

Network must use Spectrum defined in 3GPP, be generally intended for Business-Critical or Mission-Critical Operational needs, and where it is possible to identify Commercial Value,

Non-3GPP Networks such as those using Wi-Fi, TETRA, P25, WiMAX, Sigfox, LoRa and proprietary technologies are excluded from the data set.

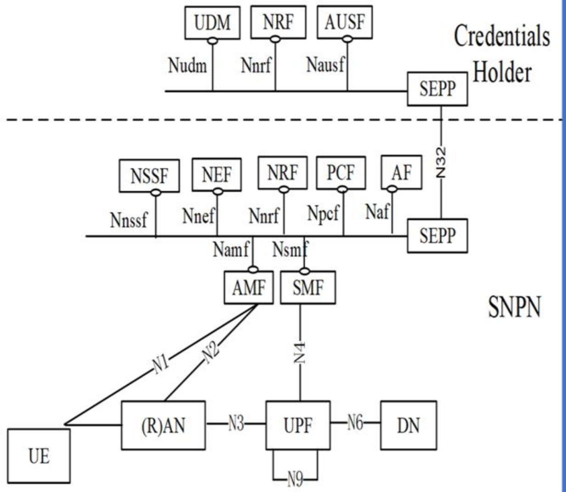


Fig. 3-1 5G System Architecture with Access to SNPN using credentials from Credentials Holder using AUSF and UDM

2. Market Definition and Deployments of "Private 5G" PNI - NPN/NSPN - 3

2.3 *GSA has been working with Executive Members* ***Ericsson, Huawei and Nokia*** *on harmonising definitions of what counts as a valid Private Mobile Network, and on harmonising sector definitions. That work has led to a re- statement of some of GSA’s market statistics.*

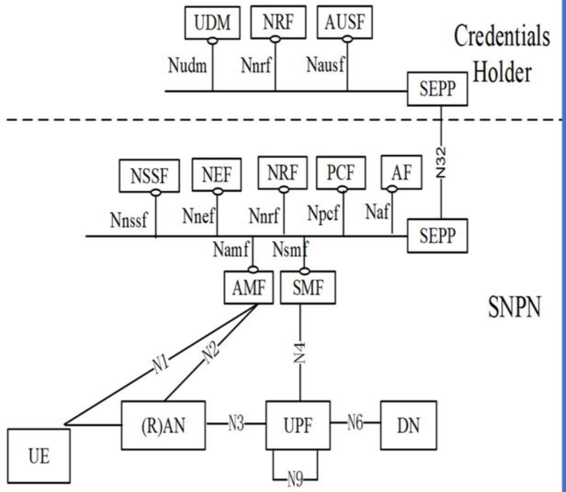


Fig. 3-1 5G System Architecture with Access to SNPN using credentials from Credentials Holder using AUSF and UDM

2.4 Private Mobile Networks *<u>are usually not offered to the General Public</u>*, although GSA's analysis does include the following:

- ***Educational Institutions that provide Mobile BroadBand (MBB)* to Student Homes**;

- *Private Fixed Wireless Access Networks* ***(PFWAN)*** deployed by **Communities for Homes and Businesses;**

- ***City or Town Networks*** that use local licences to provide wireless services in **Libraries or Public Places (possibly offering Wi-Fi with 3GPP Wireless Backhaul)** which are not an extension of the Public Network.

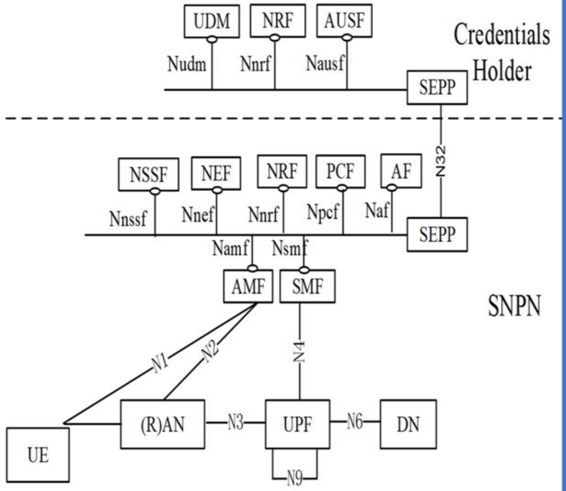


Fig. 3-1 5G System Architecture with Access to SNPN using credentials from Credentials Holder using AUSF and UDM

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

2.5 GSA has identified

- ***58 Countries and Territories*** *with Private Network Deployments based on LTE or 5G, or where* ***Private Network Spectrum Licences*** *suitable for LTE or 5G have been assigned.*

- There are *Private Mobile Network Installations in various* ***Off-shore Locations serving the Oil and Gas Industries, as well as on Ships.***

- ***656 Organisations known to be deploying LTE or 5G Private Mobile Networks.***

Since the last update of this report in November 2021, some organisations have been removed from the Data Base and this Analysis, owing to a lack of evidence that they met the definition criteria. These examples may be added again in the future.

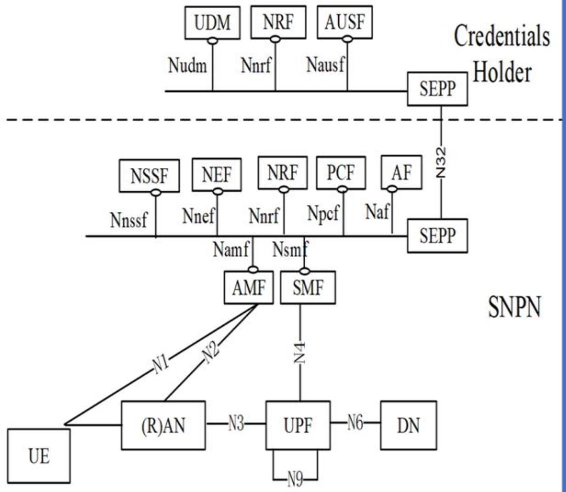


Fig. 3-1 5G System Architecture with Access to SNPN using credentials from Credentials Holder using AUSF and UDM

2. Market Definition and Deployments of "Private 5G" PNI - NPN/NSPN - 6

5G World in London <u>(September 22, 2021)</u> brought some perspective.

The Market promises so much, **<u>but the promise gets over-hyped</u>**:
1. Designing, 2. Building, and 3. Managing Private 5G is hard, remains novel,

“Until a few months ago, the assumption was that Private Networks represented a quick and easy win, with lots of revenues, and enterprises jumping in.

But it is a blank page; the Story is still to be written.

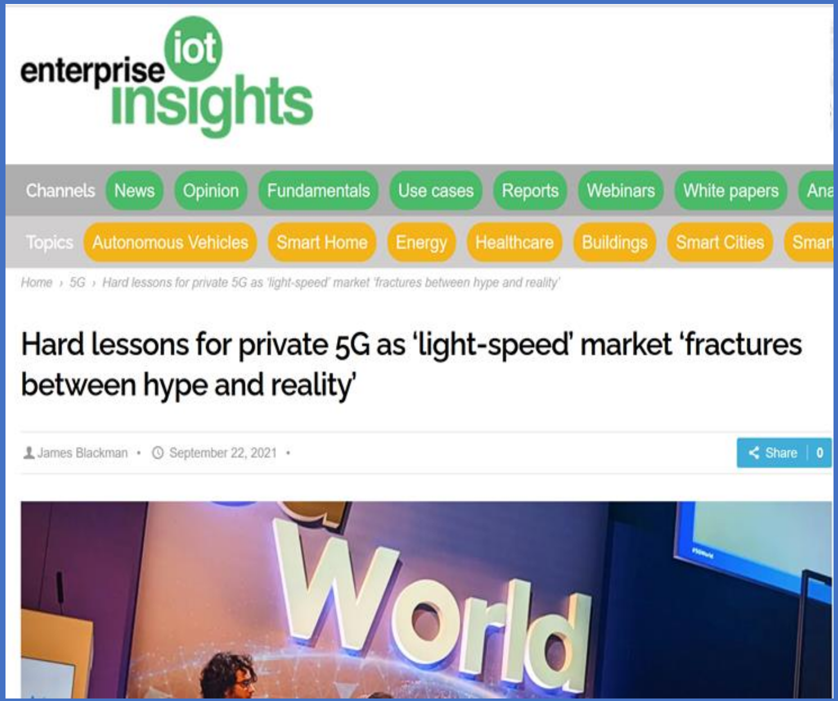
There is a Learning Curve for Enterprises, and a Learning Curve for Everyone selling Private Network Services.

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.



https://enterpriseiotinsights.com/20210922/channels/news/hard-lessons-for-private-5g-as-lightspeed-market-is-fractured-between-hype-and-reality?utm_campaign=Enterprise%20IoT%20Newsletter&utm_medium=email&_hsmi=162862354&_hsenc=p2ANqtz-_rkpszzAFyrYTATSTBWE88VSKQCqdUyAdfuNgJFBs7nlbwnCmskZSPs6Nl4Ftg77p8boVhFiPUCc-0Oklff37DT2D3cQ&utm_content=162862354&utm_source=hs_email

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***

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."

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

2. Market Definition and Deployments of "Private 5G" PNI - NPN/NSPN - 8

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

There are 1,000-plus Private Networks deployments globally, and that most of these are in China.

"in China, the Industry assumes there are several 100 Private Network deployments, but only 40 are fully Publicly disclosed" – …. the number of deployments in China is higher;

Most deployments in China use this Public-Private (Non-Public) Network Integration (PNI-NPN) Model - where the UPF runs off the Public Network, allied with Local-Area Private Radios.

Comparing success in Germany / Europe with China is difficult – because China is so heavily reliant on Carriers pushing hard. What do you make of this?

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

"Alarming" - Private 5G Window is closing to Telcos, almost before it opens. August 20, 2021

1. Germany's interest in Private Networks is fading," says ABI. "[And] other European countries are lagging far behind."

The basis for their crisis is that 'Vertical' spectrum applications, available to enterprises on 10-year deals for the same outlay as a decent phone contract, have *slowed in Germany, from around 80 in the 1st half of 2020 (40 per Quarter on average) to "only" 20 in the 2nd Quarter of 2021* – representing an compound reversal of about 50% in the period.

….the German regulator, has so far issued 146 licences for local-area 5G in Germany.

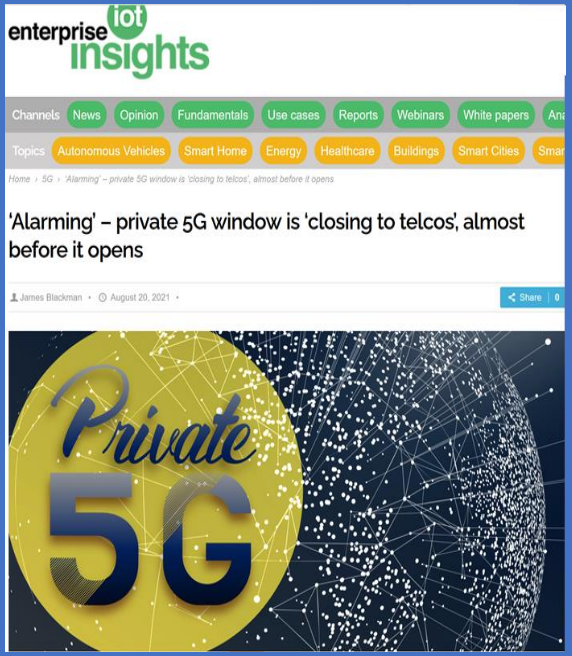
It puts the number of Publicly-disclosed Private Network Deployments at 290, globally, including 40-odd official deployments in China.

https://enterpriseiotinsights.com/20210820/channels/news/alarming-private-5g-window-is-closing-to-telcos-almost-before-it-opens

2. Market Definition and Deployments of "Private 5G" PNI - NPN/NSPN - 10

2. The other concern for ABI is that in Europe, headlined by activity in Germany, the Private 5G Agenda is being driven by **Vendor Sales Strategies**, **rather than by Enterprise Transformation Strategies.**

Most deployments in Germany are Sales-driven; only a few are really used to enhance enterprise workflows and operations.



https://enterpriseiotinsights.com/20210820/channels/news/alarming-private-5g-window-is-closing-to-telcos-almost-before-it-opens

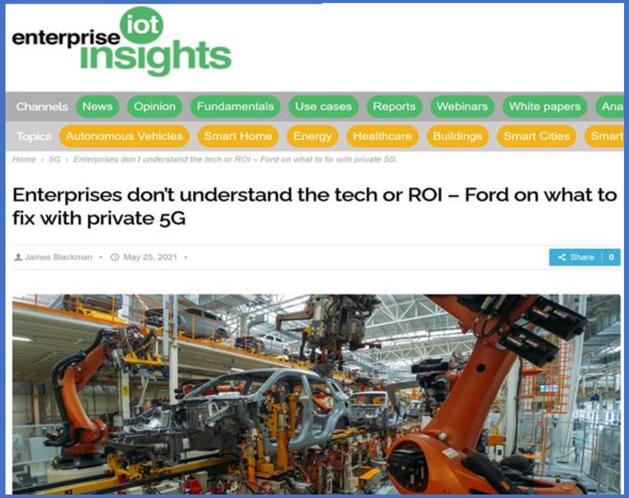
"In China, almost all Deployments are for Real-Life Enterprise Use-Cases (UCs), motivated by Demand.

3. In Germany, most Private Networks are [sold] by System Integrators (SI) or Factory Automation Vendors **to showcase 5G [and to] integrate their Product offerings."**

"The Telco Industry must realize that the Value proposition for Enterprise 5G does not lie in the Technology, but in the Applications it enables.

No Enterprise cares about whether they deploy 4G or 5G, as long as it solves their pain points."

2. Market Definition and Deployments of "Private 5G" PNI - NPN/NSPN - 11



Enterprises don't understand the Tech or ROI – *Ford* on what to fix with Private 5G May 25, 2021

But speaking plainly at today's Private Networks Forum event, Automotive Manufacturer Ford said the onus is on the two (2) sides to meet halfway, and suggested:

"Industrialists, in fact, are pretty clueless about Industrial 5G in general"

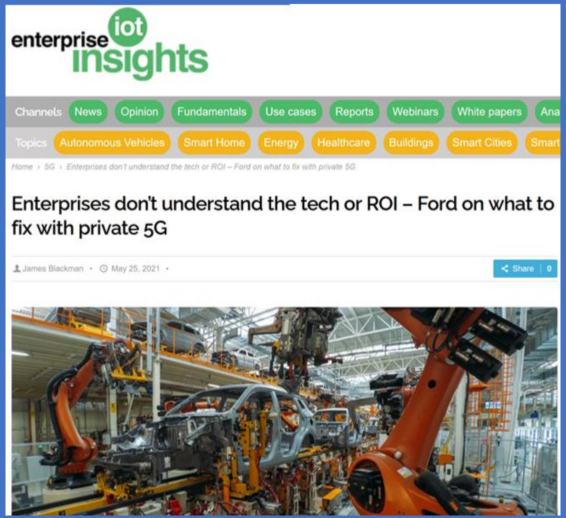
Chris White, electrification manager for Ford's European Business, commented:

"Our understanding was really poor at the start.
We've been in this a year, working with Vodafone, and we have built-up that understanding.

But… that understanding about [industrial 5G] is very poor outside of the Telecoms world."

2. Market Definition and Deployments of "Private 5G" PNI - NPN/NSPN - 12

Enterprises don’t understand the Tech or ROI – Ford on what to fix with Private 5G, May 25, 2021



Sharing a panel with Ericsson, Mavenir, and Radisys,

Chris White ran through some of the preceding topics in the panel session at Private Networks Forum:

“Standalone (SA), Non-Standalone (NSA), all the latest 3GPP Releases:

1. **[There is a lack of understanding about] all these things we have talked about, and**
2. **What they mean for Enterprises.”**

He added: “Helping Enterprises with that Knowledge is really important.”

At the same time, White warned that:

5G is a "Means-to-an-End": the subtext is the Telecoms community is inclined to present it as the Solution, instead – as per the criticism, referenced above, levelled at the sector by enterprises.

“5G is just an Enabler: There is no Business Case for 5G,” he said.

Ref. Demonetizing Everything. A post Capitalism World, Peter Diamandis, Sngularity Univ Summit, 2017

3. Examples of PNI-NPN/SNPN Standard defined Configurations and Capabilities (re.: KIs/UCs & Solutions)

Access to Services in PNI - NPN/SNPN Configurations

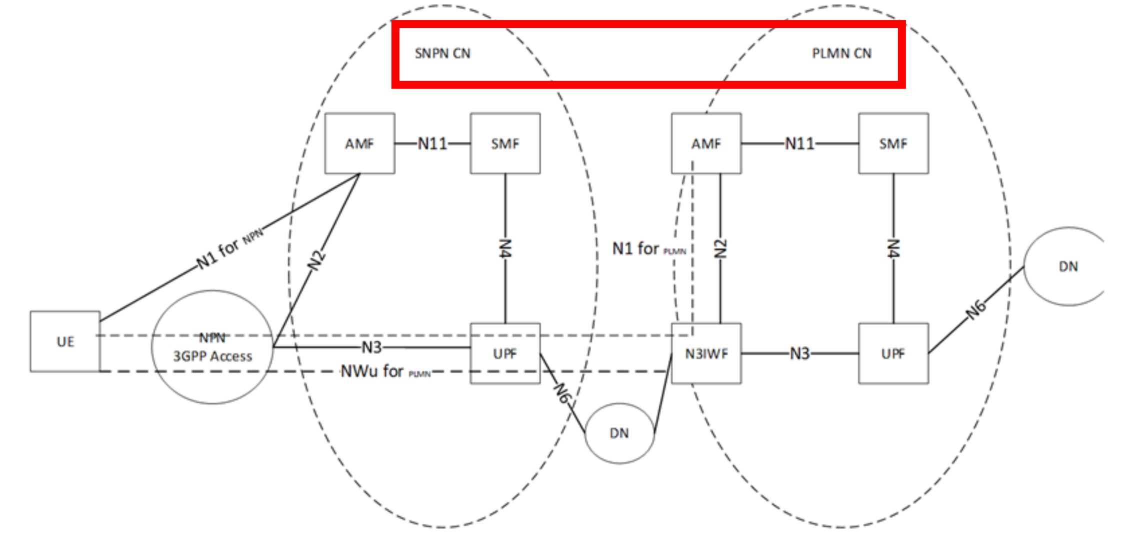


Figure D.3-1: Access to PLMN services via Stand-alone Non-Public Network

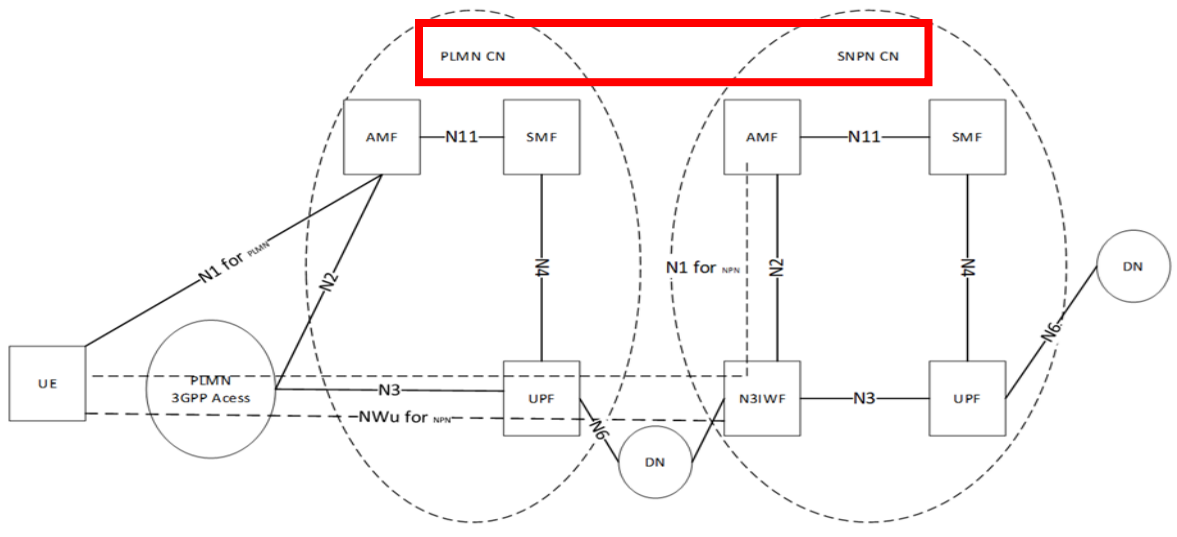


Figure D.3-2: Access to Stand-alone Non-Public Network services via PLMN

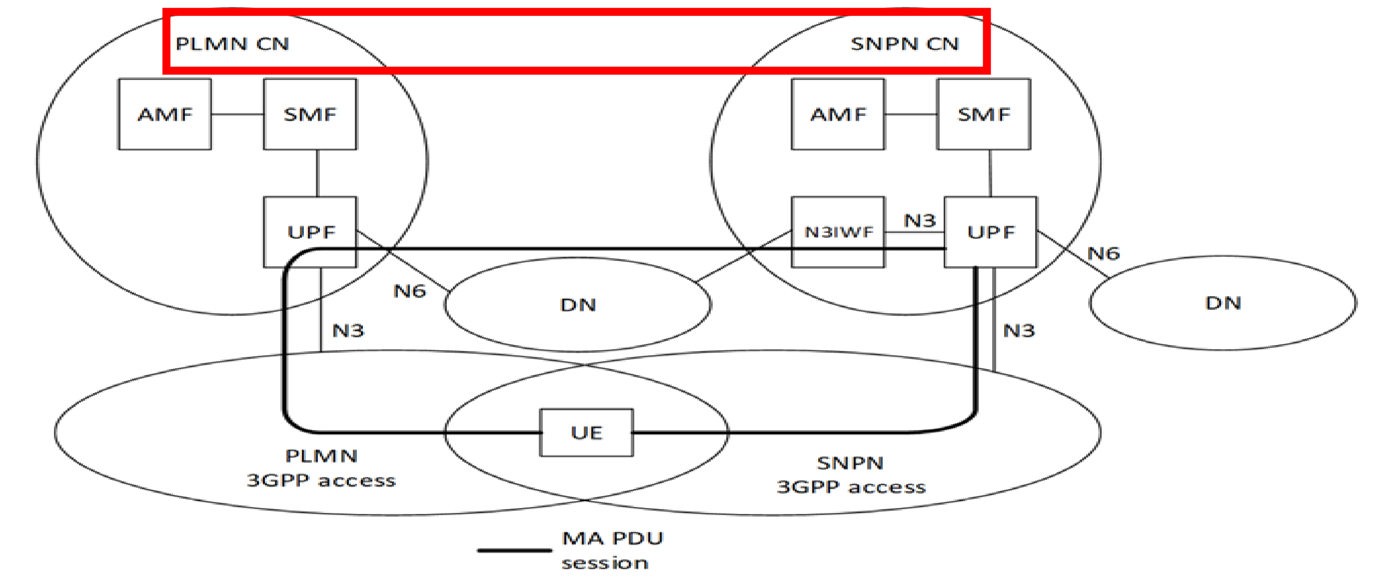


Figure D.6-1: MA PDU session with ATSSS support for dual radio UE accessing to Stand-alone Non-Public Network services via Uu and NWu interfaces

3. 3GPP Definition of PNI - NPN/SNPN with Diagrams - 2

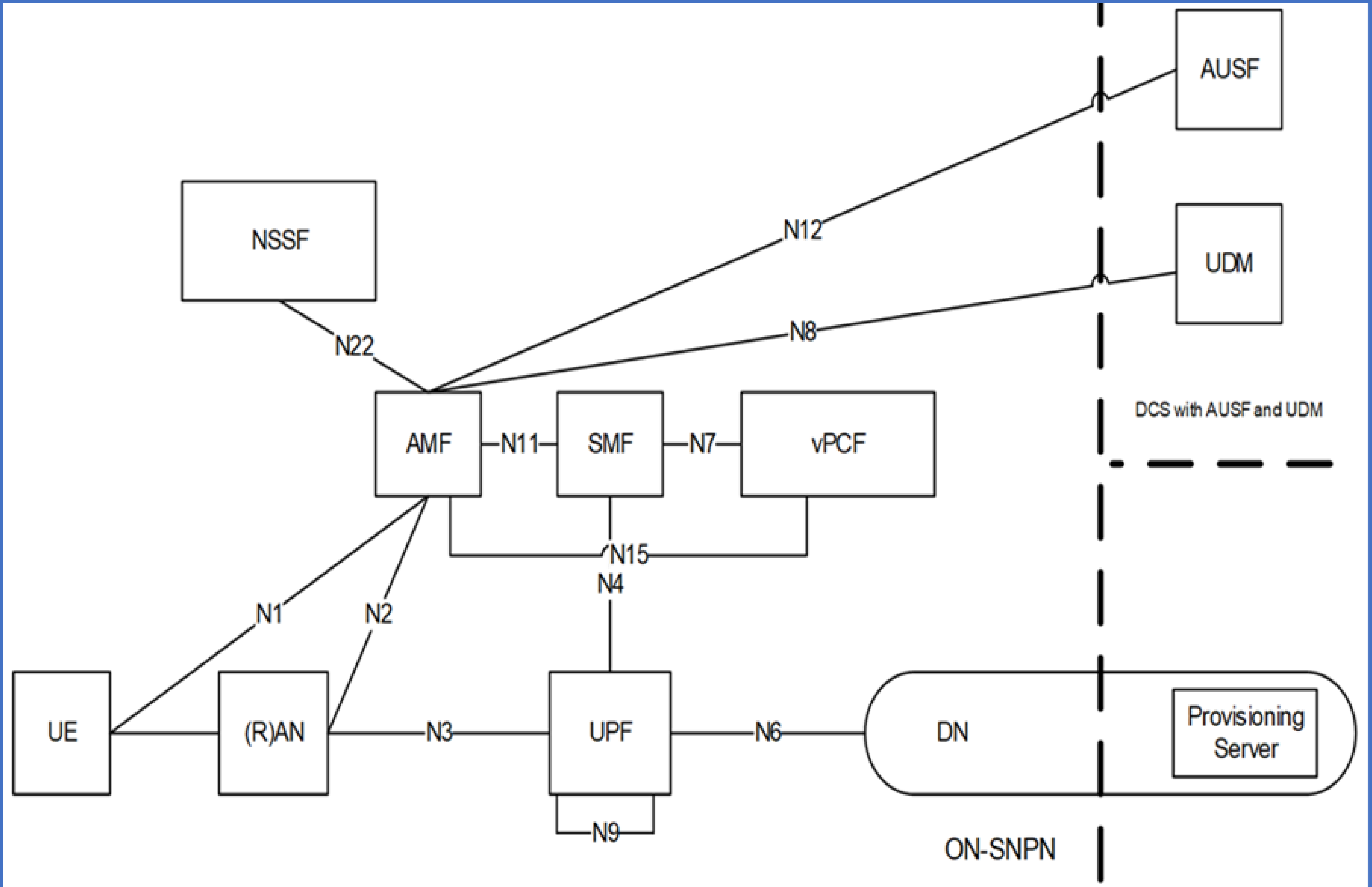


Fig.: Architecture for UE Onboarding in ON-SNPN when DCS includes AUSF and a UDM

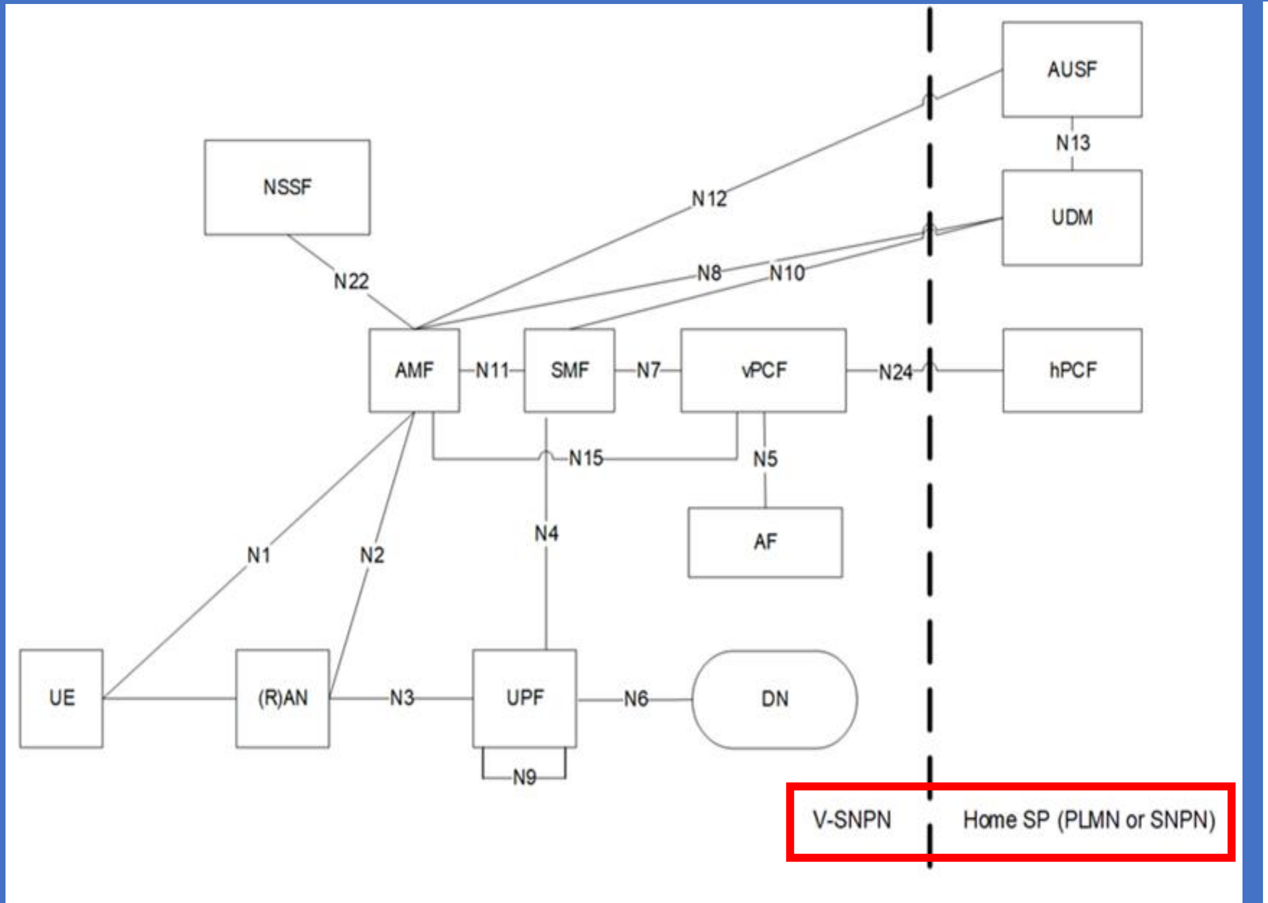


Figure 6.2.2.2-1: Access to V-SNPN services (e.g. local IP access or Internet access) using home SP credentials for authentication in the V-SNPN

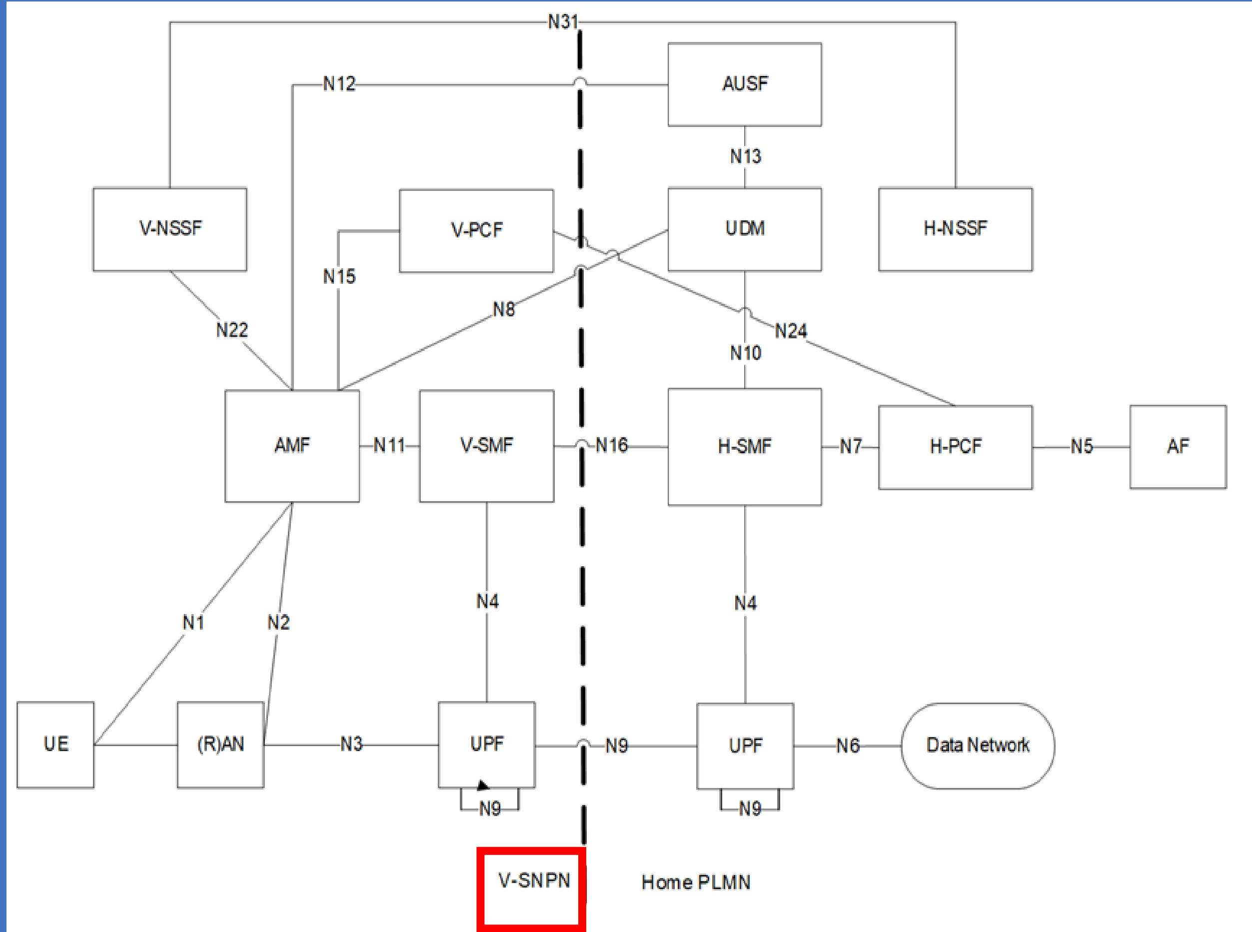


Figure 6.2.2.2-2: Access to Home PLMN services using a home-routed PDU session.

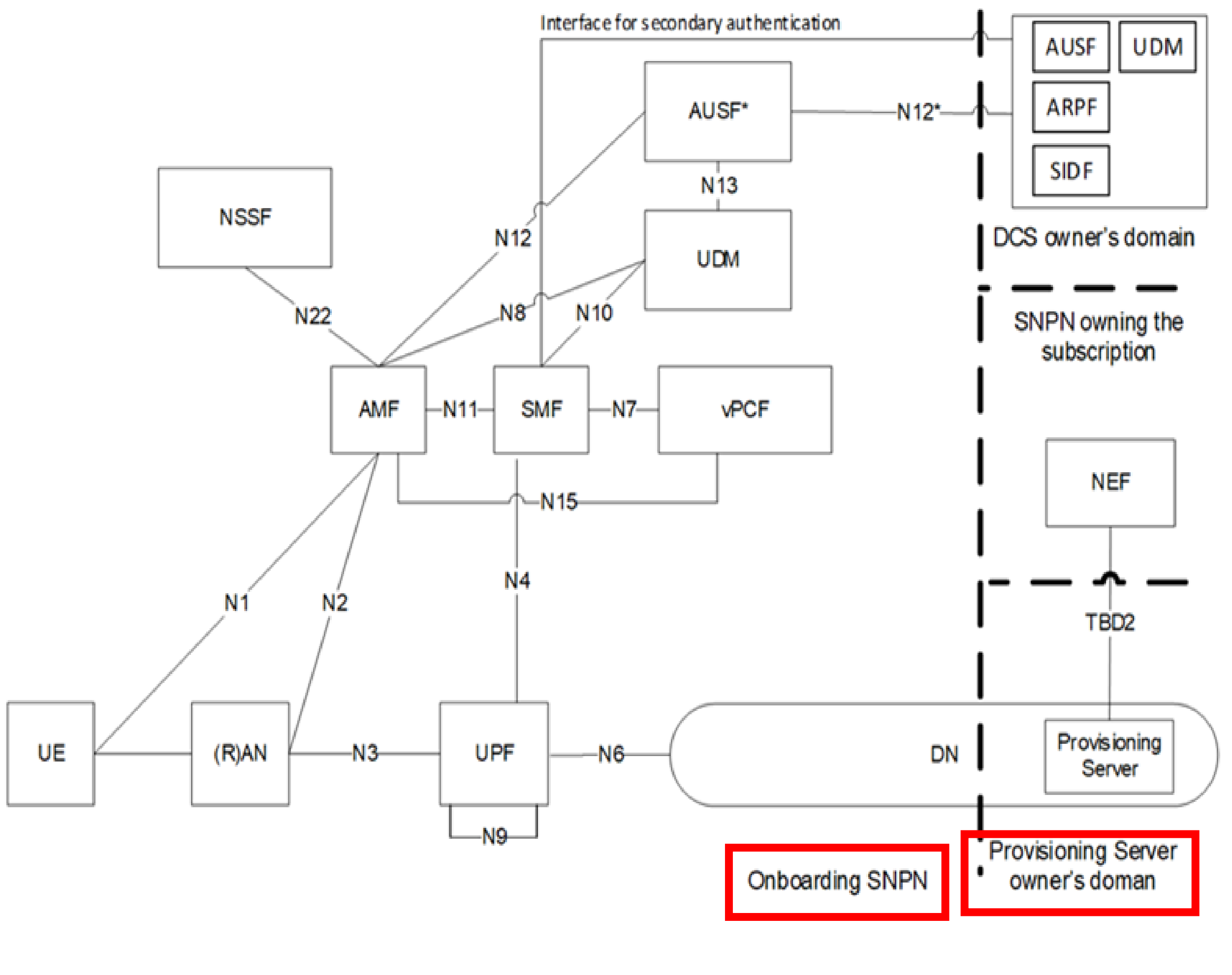


Figure 6.5.2.2-1: Architecture for UE Onboarding to an SO-SNPN

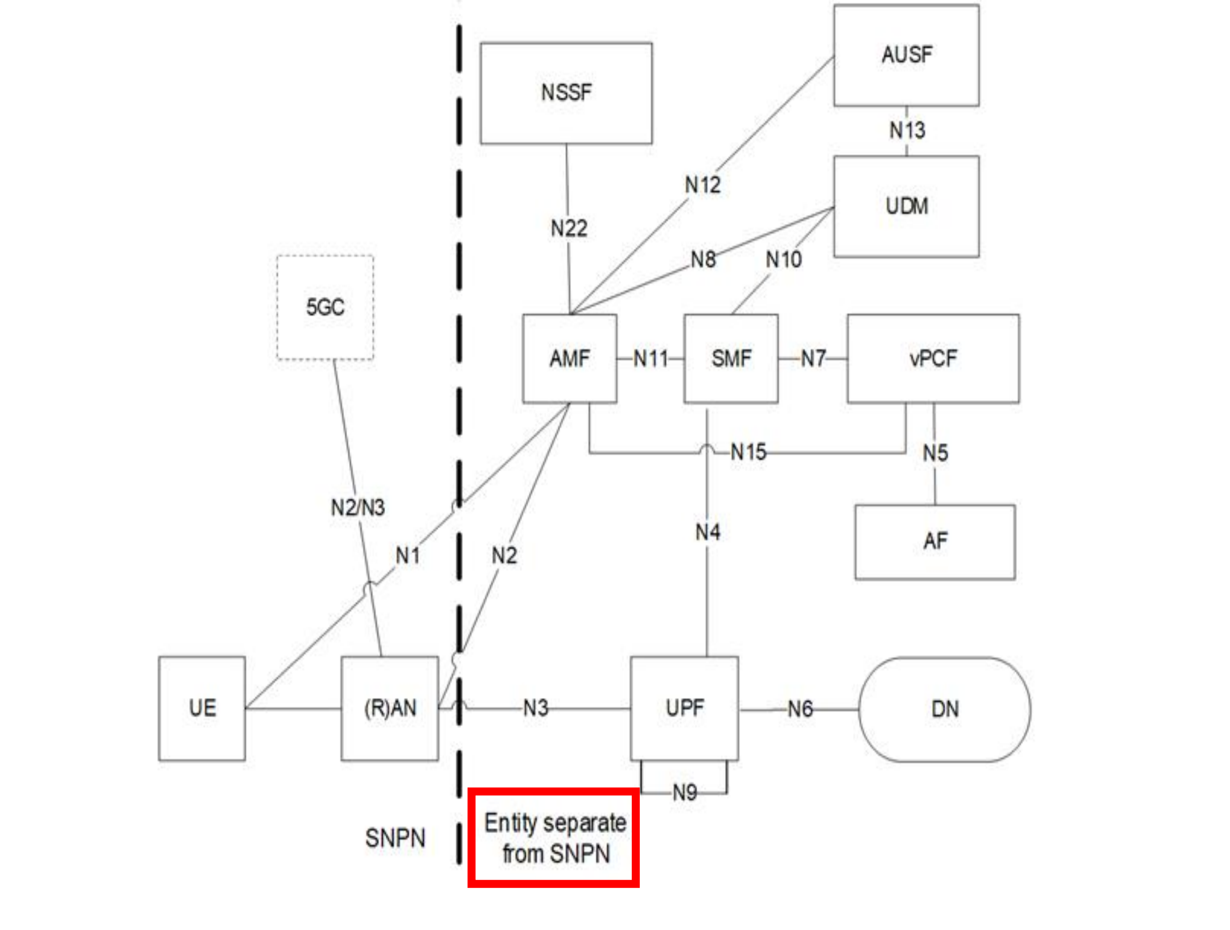


Figure 6.3.2.1-1: Access to SNPN services using credentials from entity separate from SNPN for authentication in the SNPN

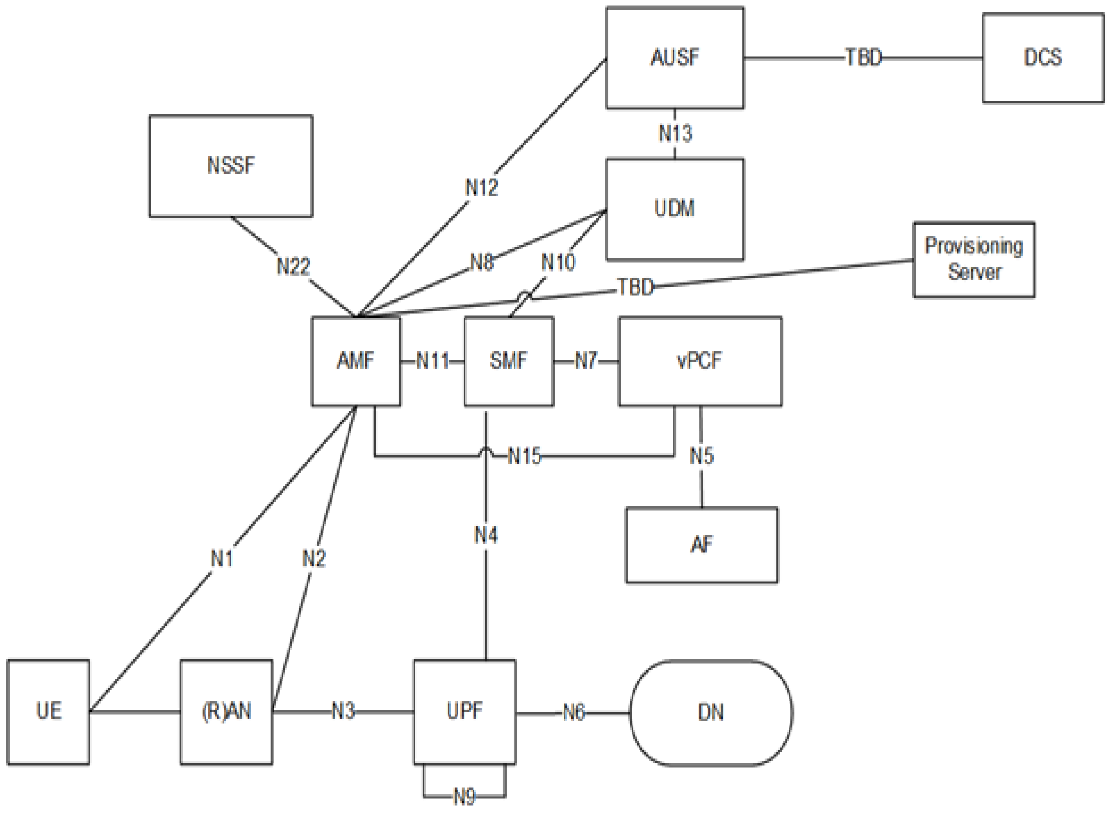


Figure 6.6.2-1: Control Plane-Based Onboarding architecture

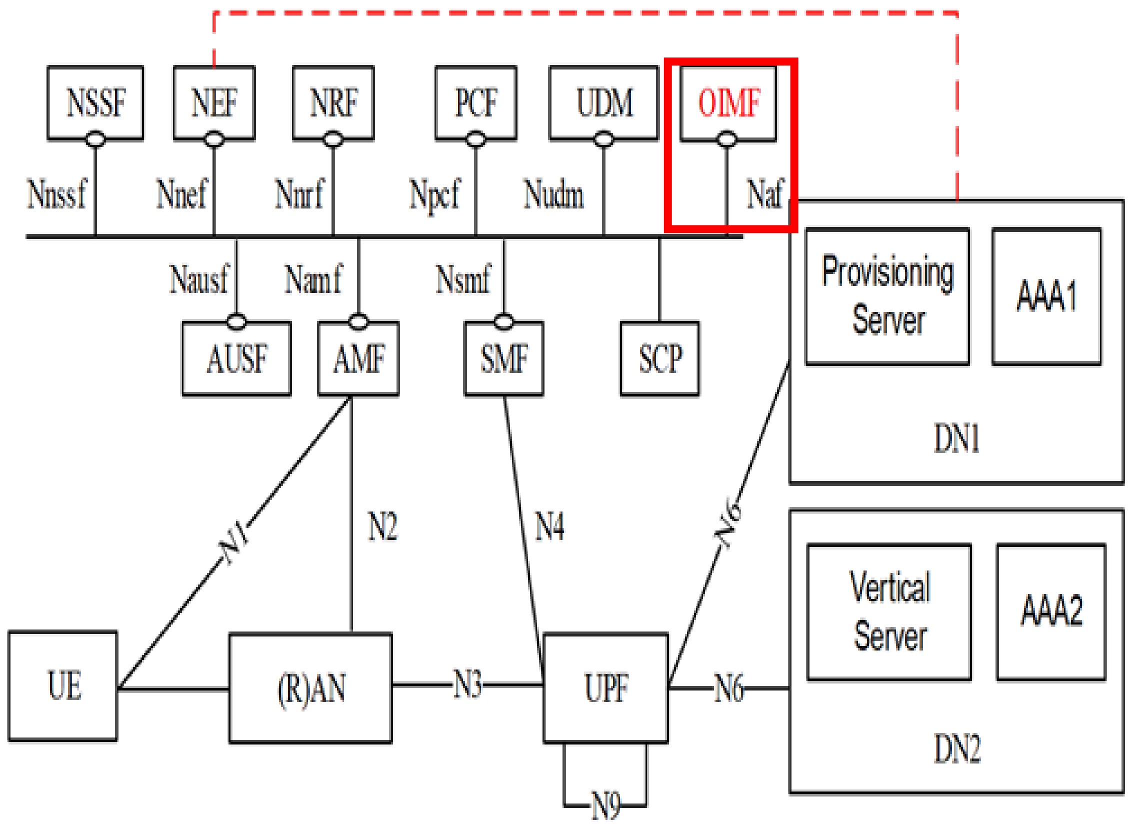


Figure 6.7.2.2-1: Architecture for UE Onboarding to a PNI-NPN

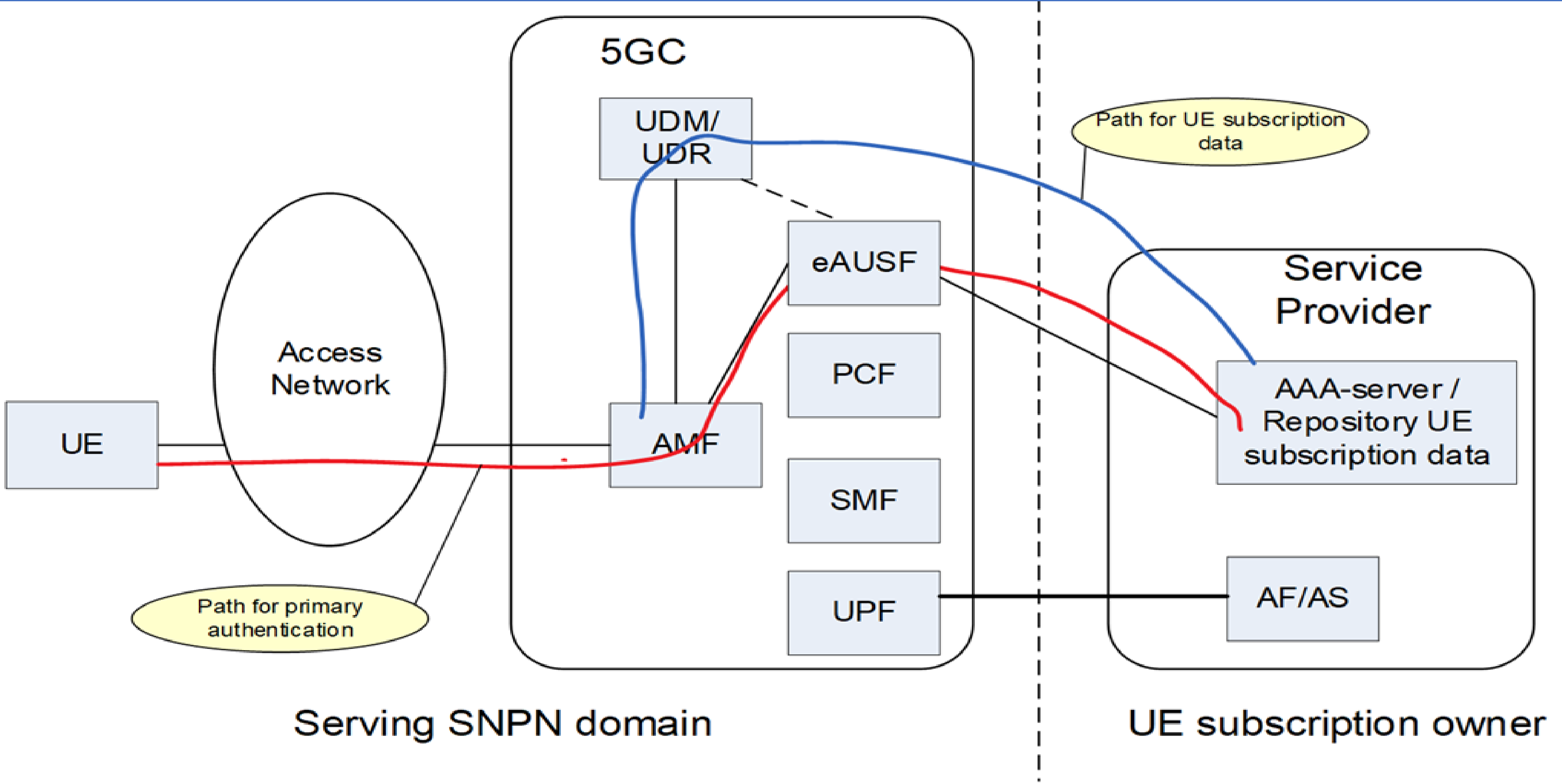


Figure 6.10.1-1: Architecture for storing the UE subscription data in the SNPN while the security signalling is performed to the SO

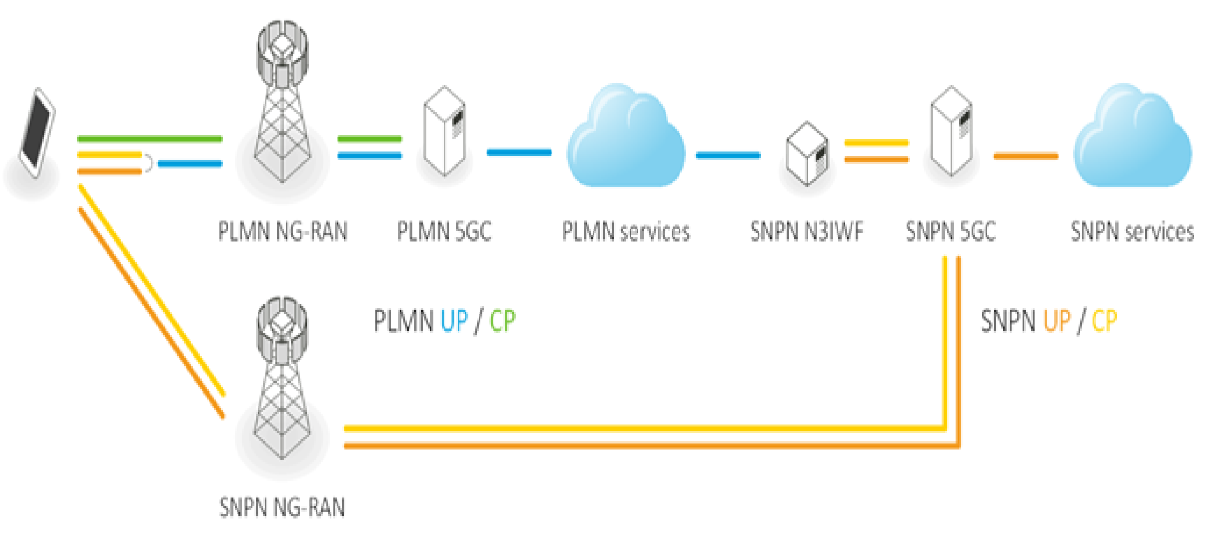


Figure 6.15.2.1-1: Concurrent accesses to an SNPN for Session and Service Continuity (Dual-radio UE)

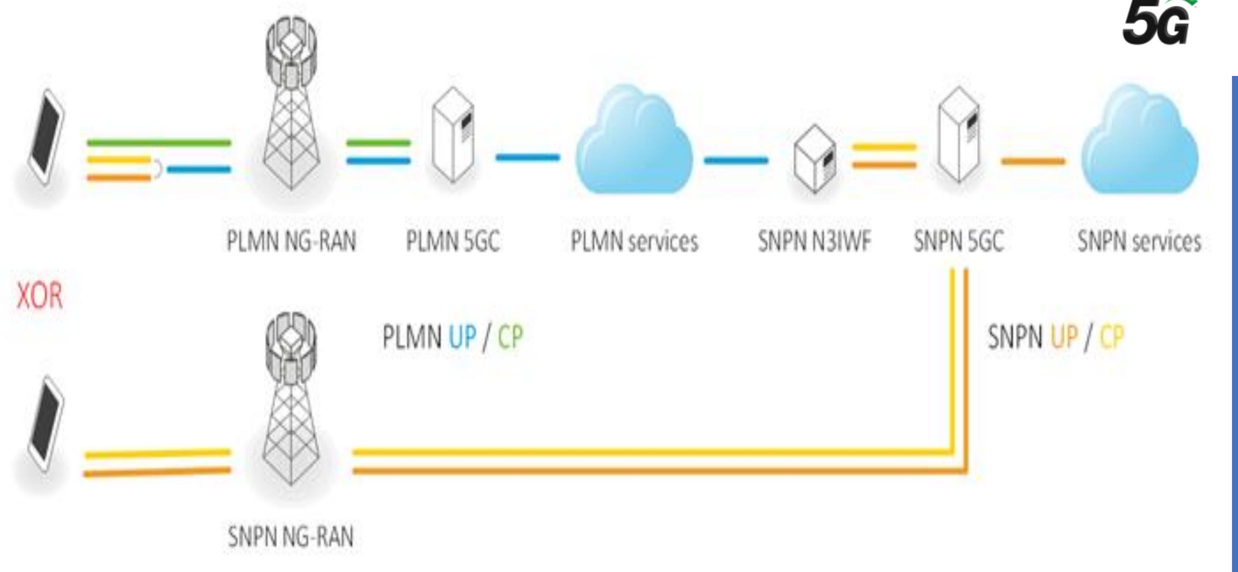


Figure 6.15.2.1-2: Distinct accesses to an SNPN for a single radio UE

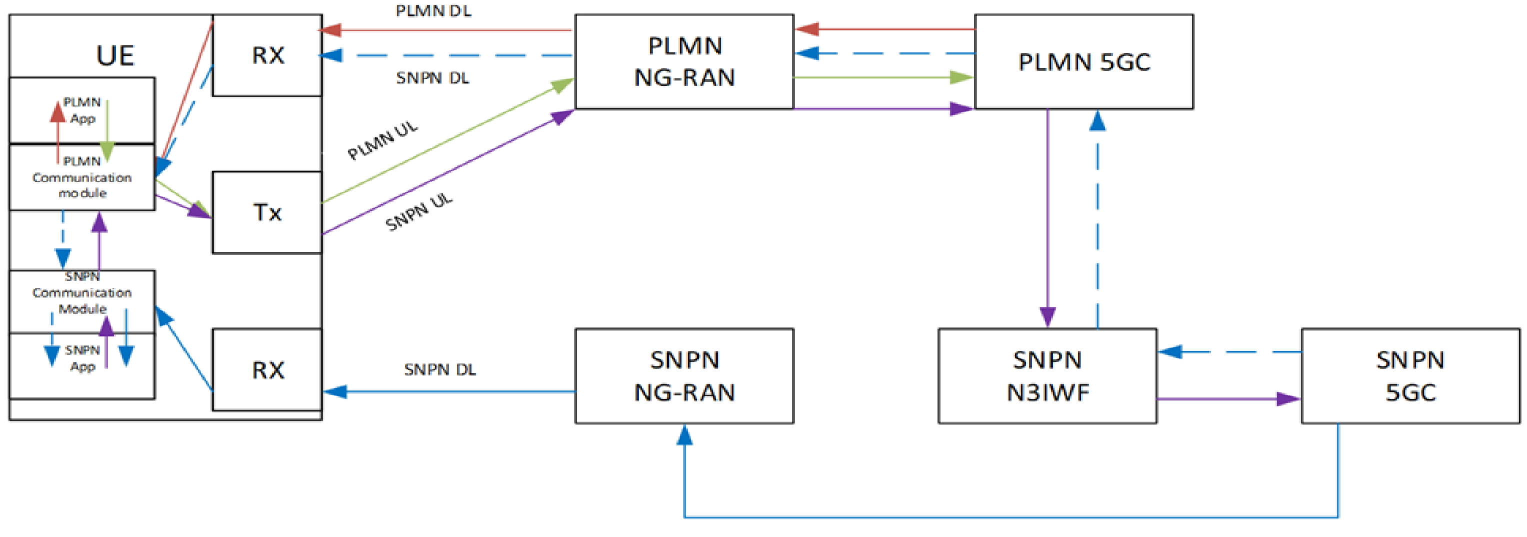


Figure 6.18.2.2-1: Architectural overview of a 2Rx/1Tx dual radio UE simultaneously connected to a SNPN and a PLMN

Ref.: 3GPP, Rel. 17

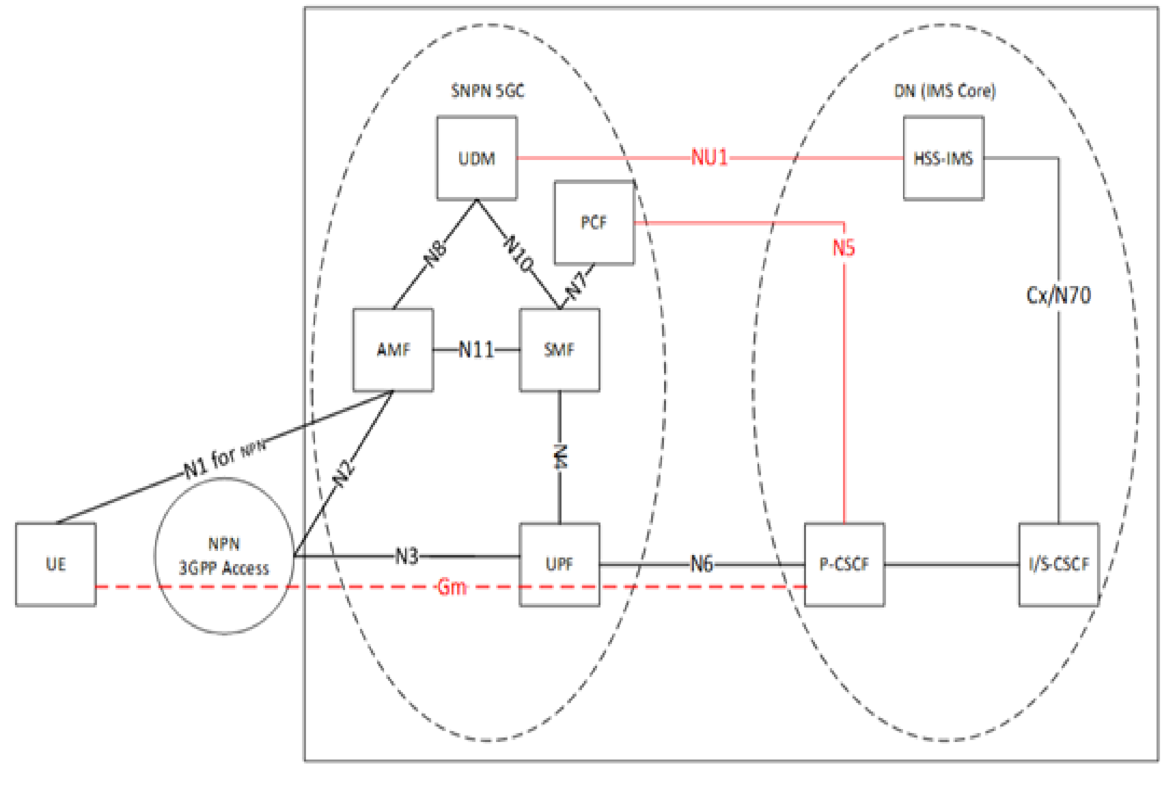


Figure 6.20.2.1-1: Access to IMS services via Stand-alone Non-Public Network

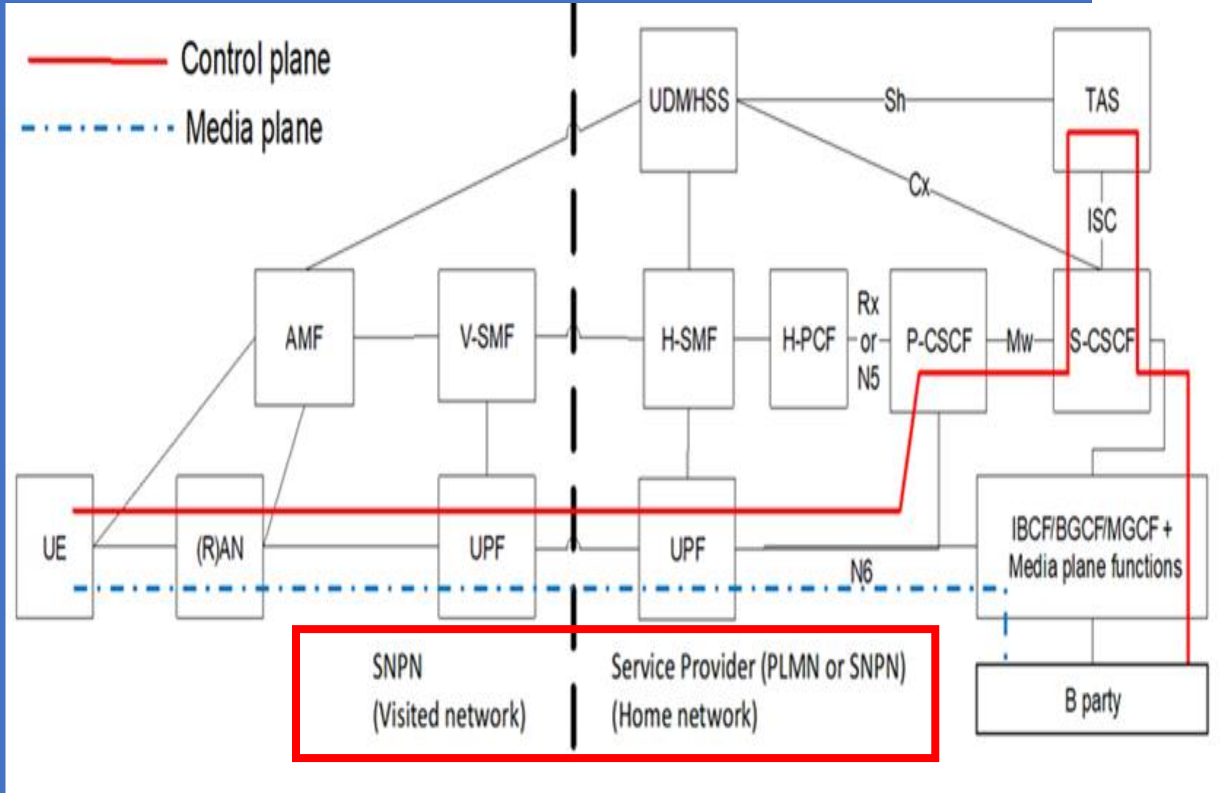


Figure 6.24.2-1: IMS traffic home routed

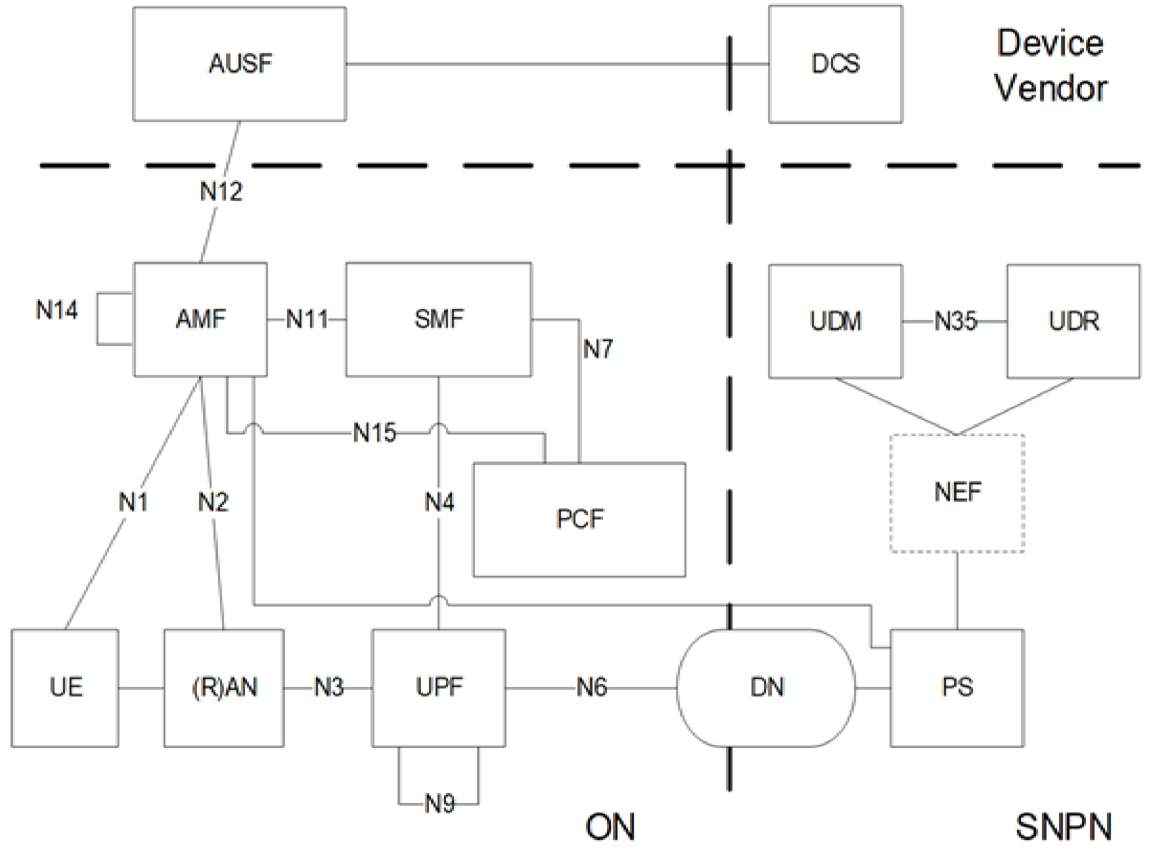


Figure 6.27.2.2-1: Architecture for UE Onboarding to an SNPN

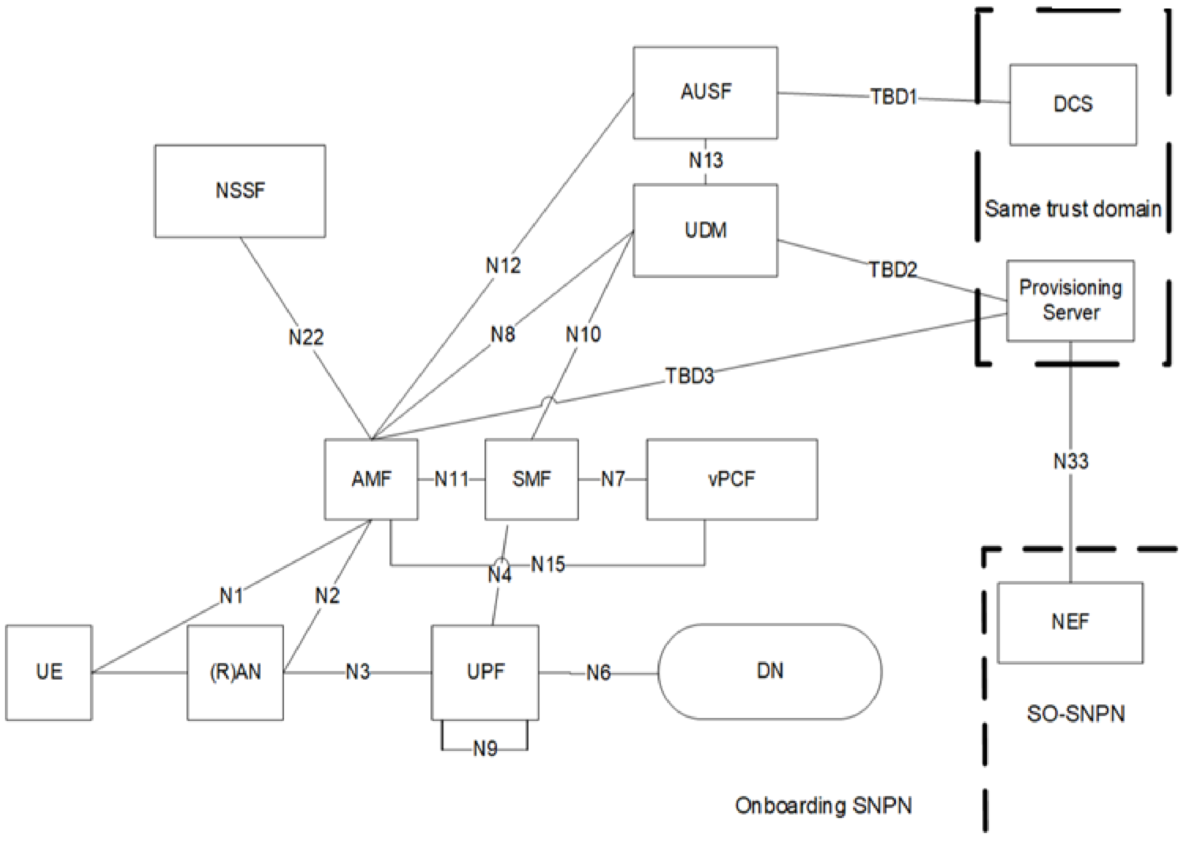


Figure 6.30.2-1: Control Plane-Based Onboarding architecture

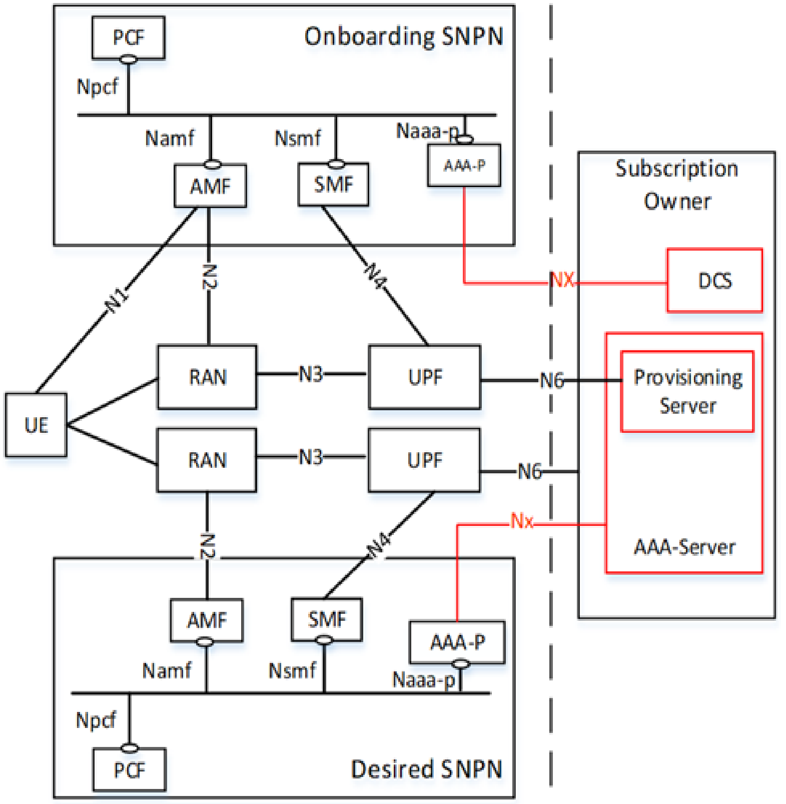


Figure 6.31.2.1-1: Architecture in case network entity for provisioning is deployed by the SNPN Operator or the Vertical, onboarding 5G network is SNPN

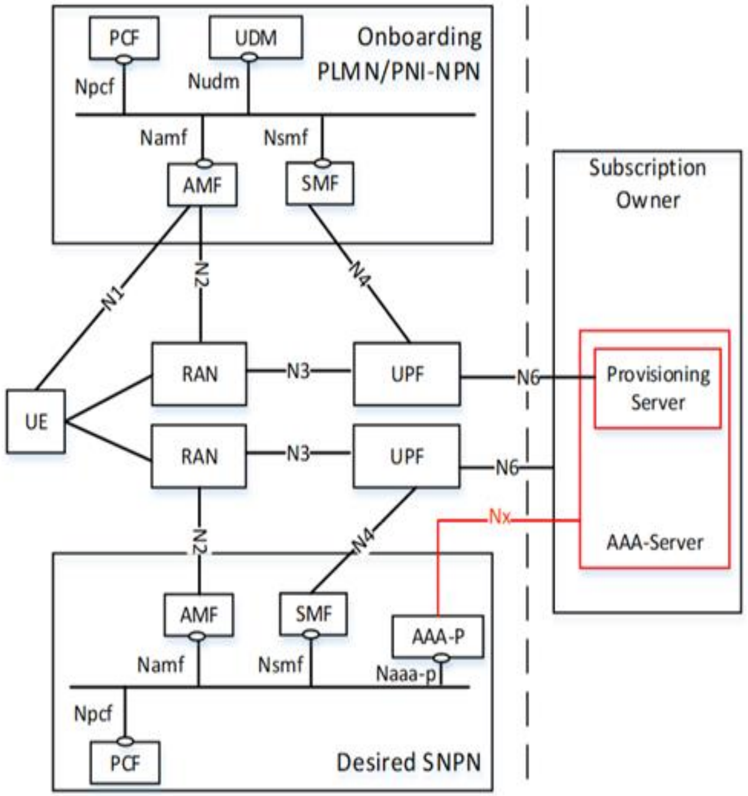


Figure 6.31.2.1-1: Architecture in case network entity for provisioning is deployed by the SNPN Operator or the Vertical onboarding 5G network is PLMN or PNI-NPN

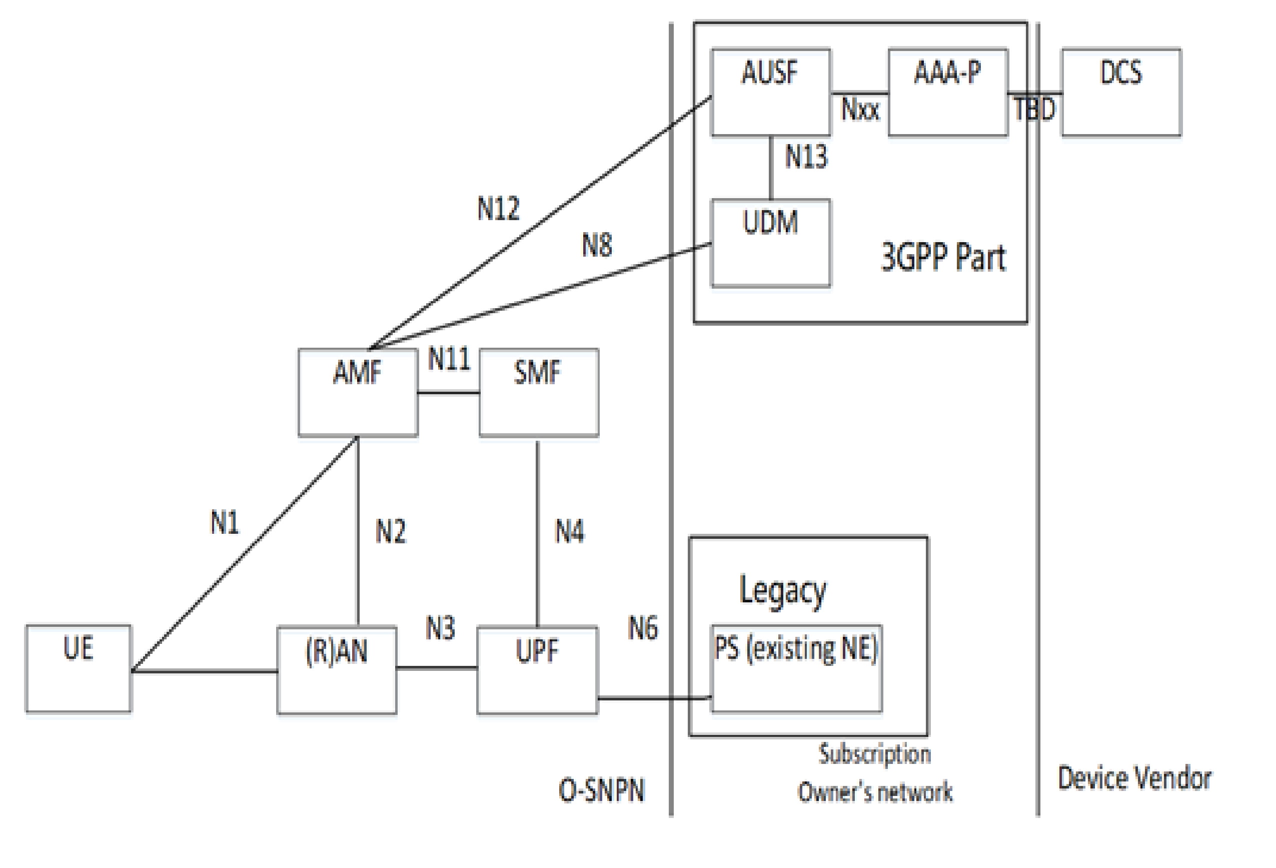


Figure 6.35.2.2-1: Architecture for UE Onboarding to an SNPN

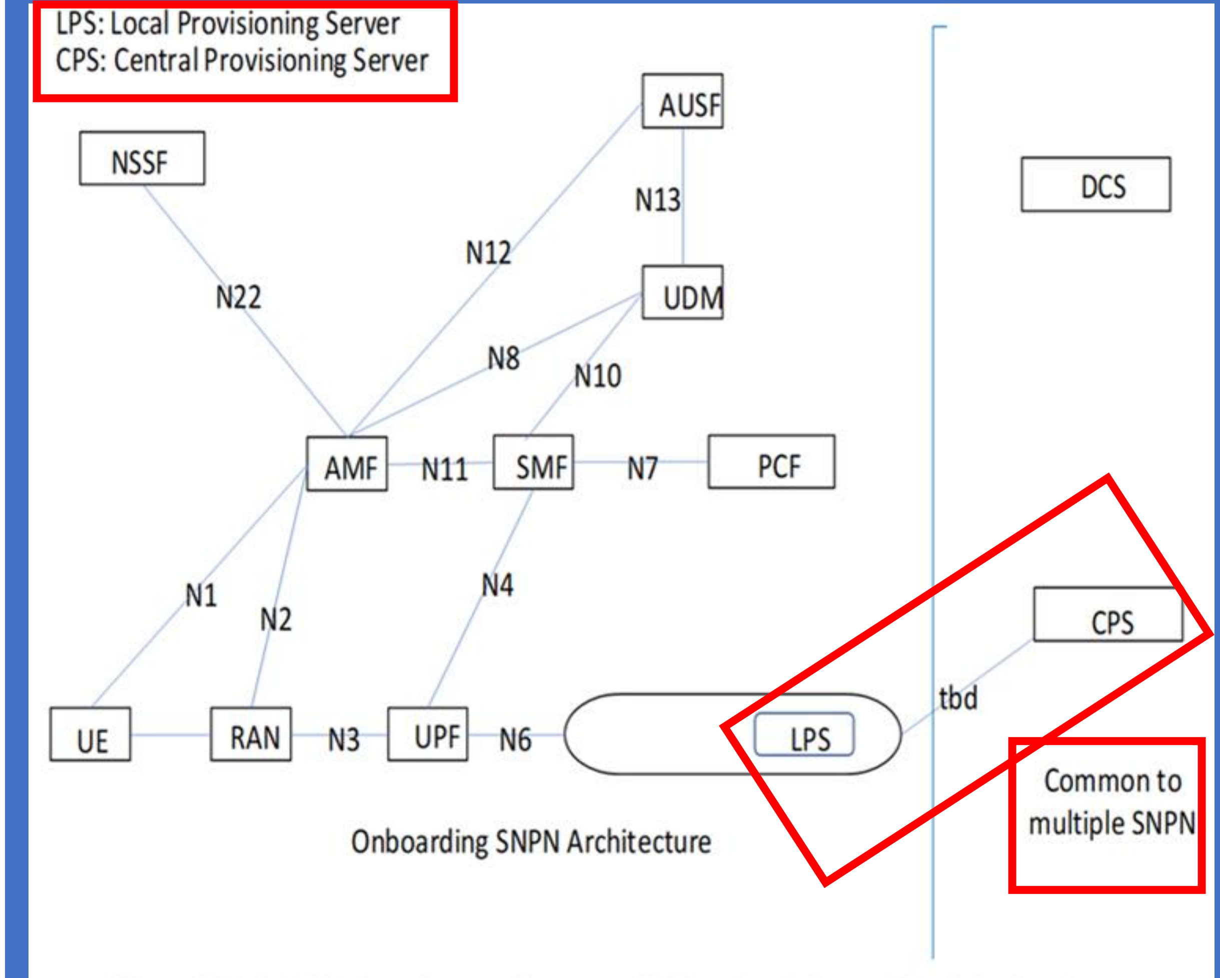


Figure 6.36.2.2-1 Onboarding architecture with Local and Central Provisioning Servers

Ref.: 3GPP, Rel. 17

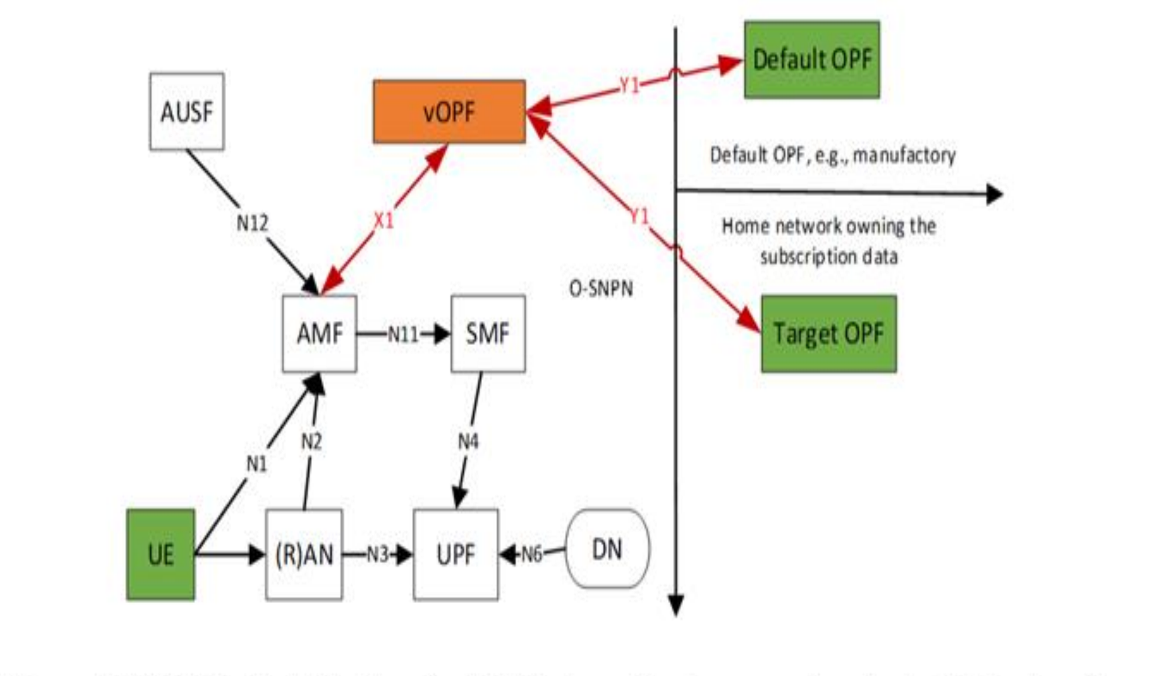


Figure 6.37.2.2-3: Architecture for UE Onboarding home network via OPF relocation

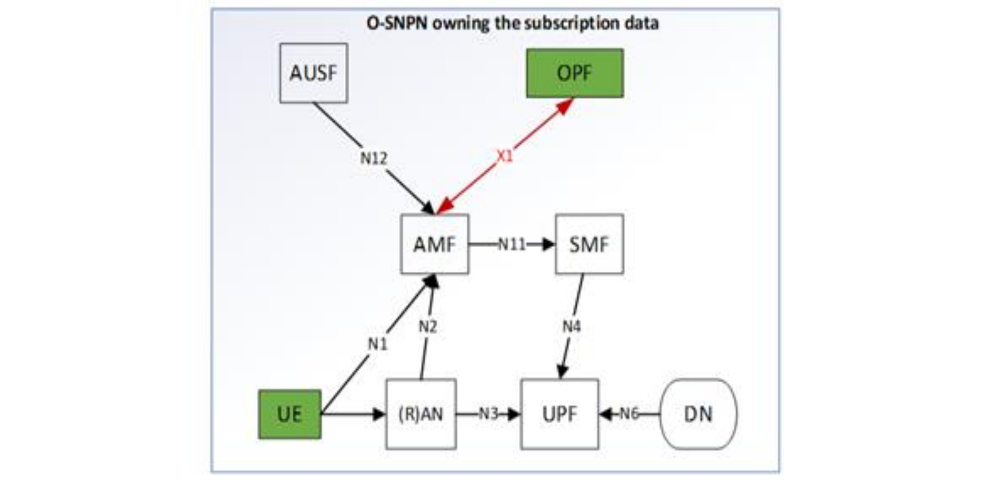


Figure 6.37.2.2-1 architecture for UE onboarding home network (O-SNPN)

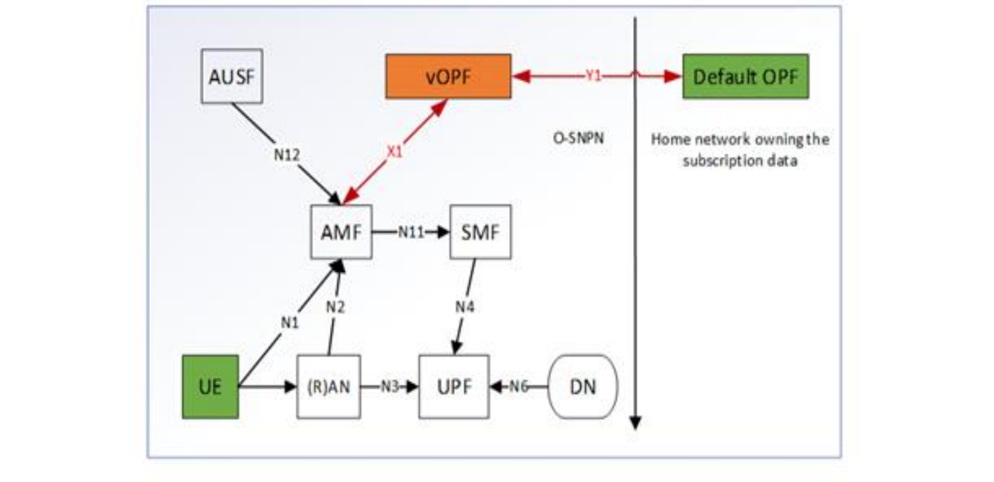


Figure 6.37.2.2-2 architecture for UE onboarding home network via O-SNPN

Solution #44: UE external subscription data management in the SNPN

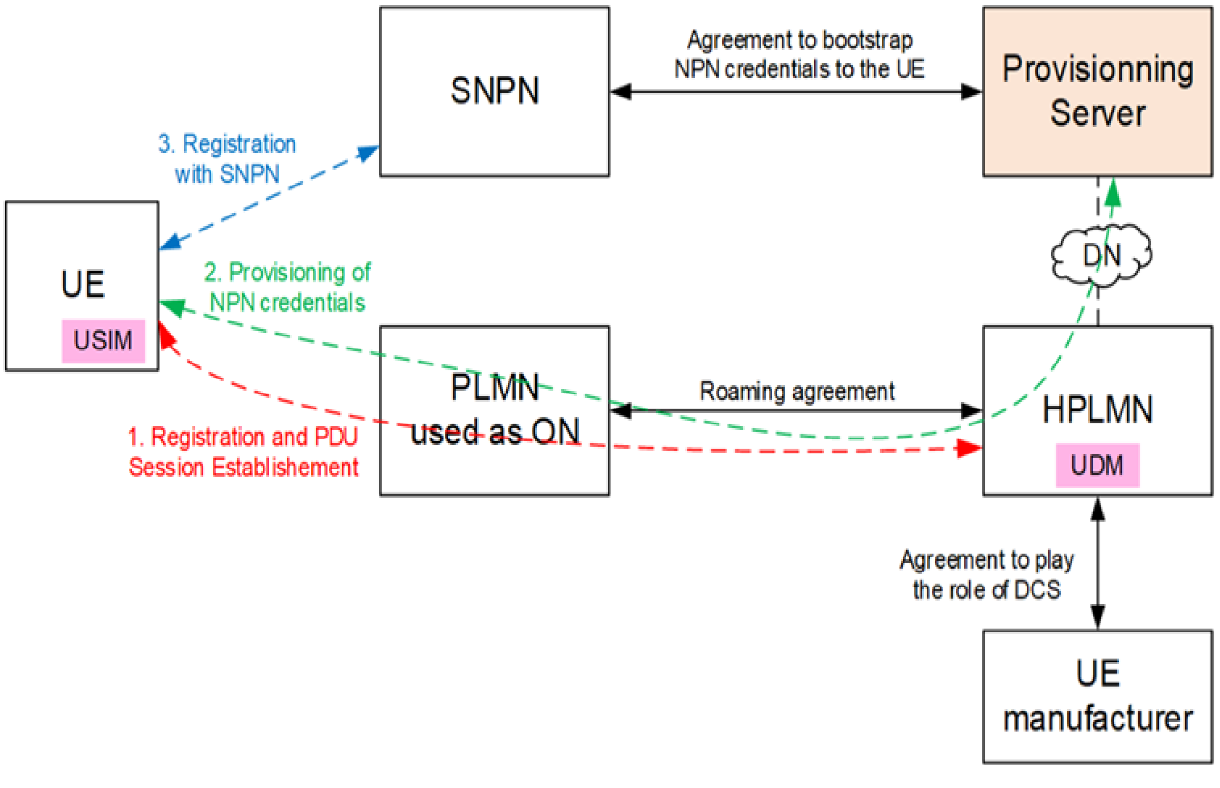


Figure 6.39.1-1: UE onboarding using PLMNs

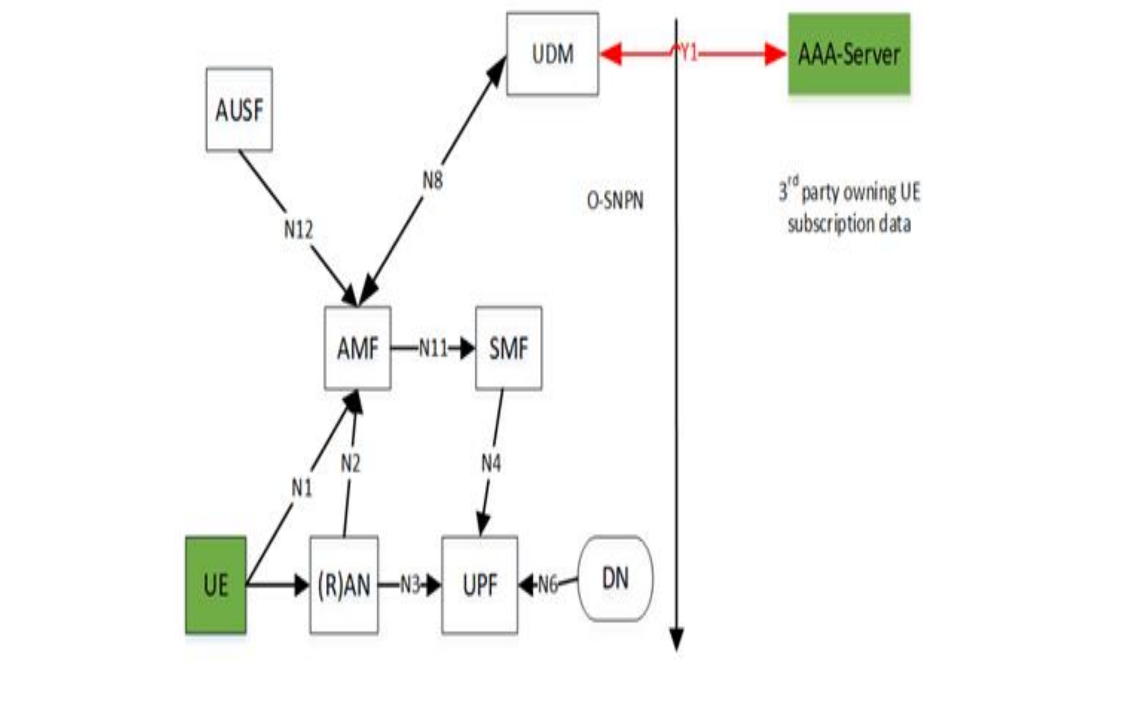


Figure 6.44.2.2-1 architecture for UE external subscription data exchange between UDM and AAA-Server

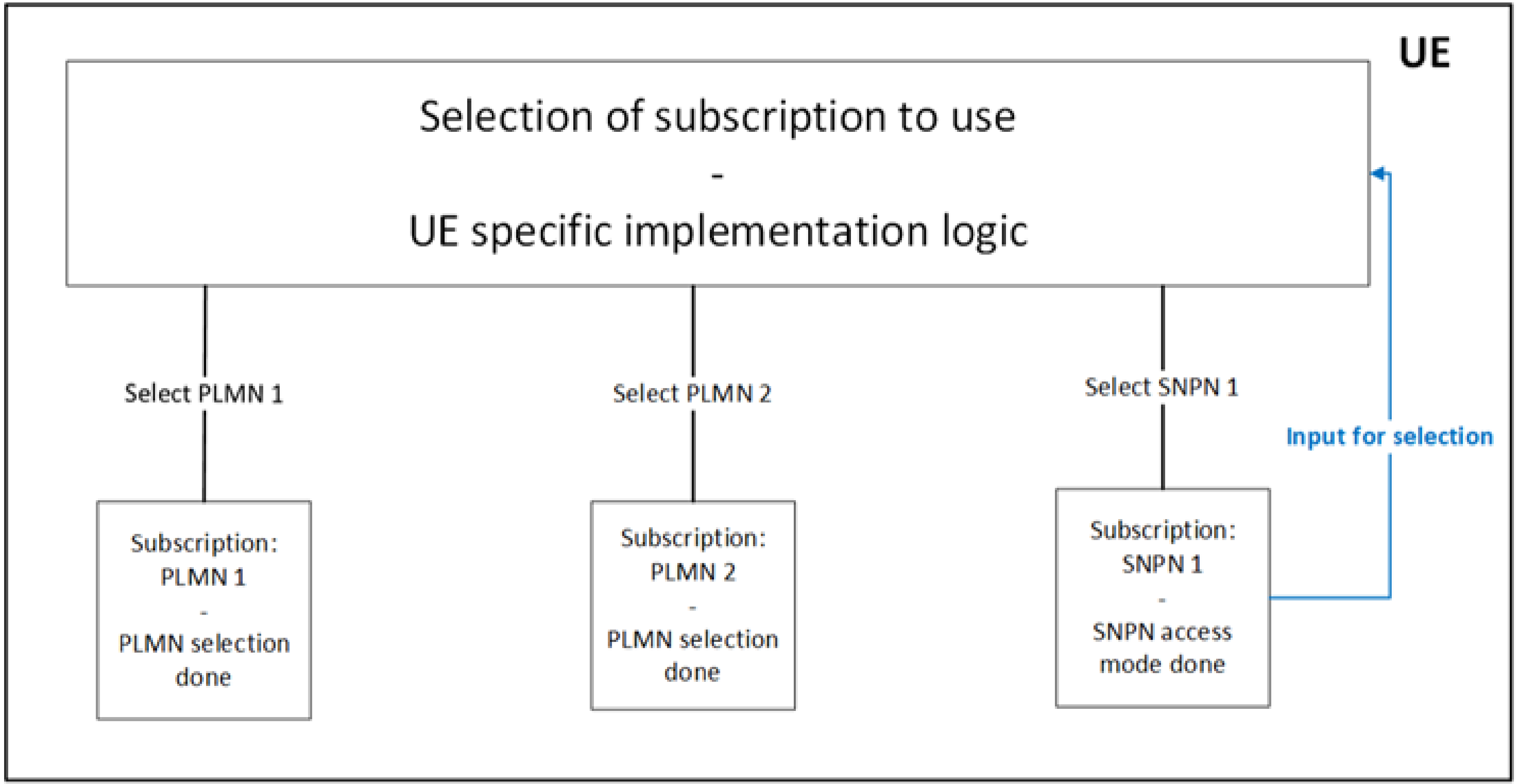


Figure 6.46.3.2-1. input for selection of subscription in the UE to use for Network selection

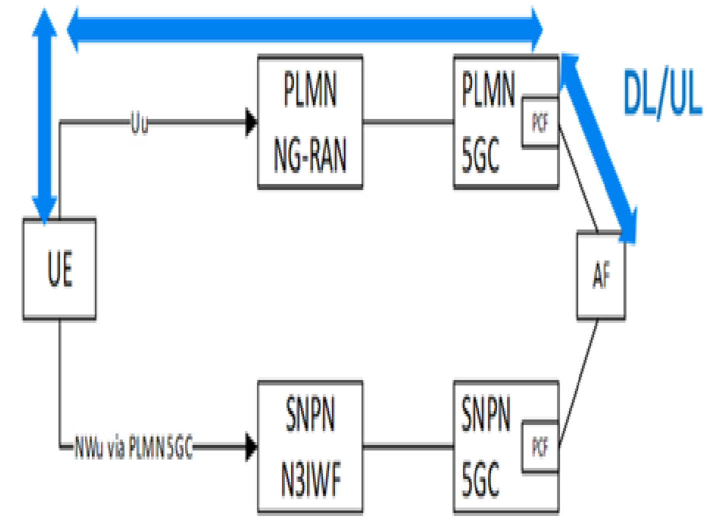


Figure 6.46.1-1. VIAPA traffic delivered over PLMN. The UE is connected to PLMN via Uu interface

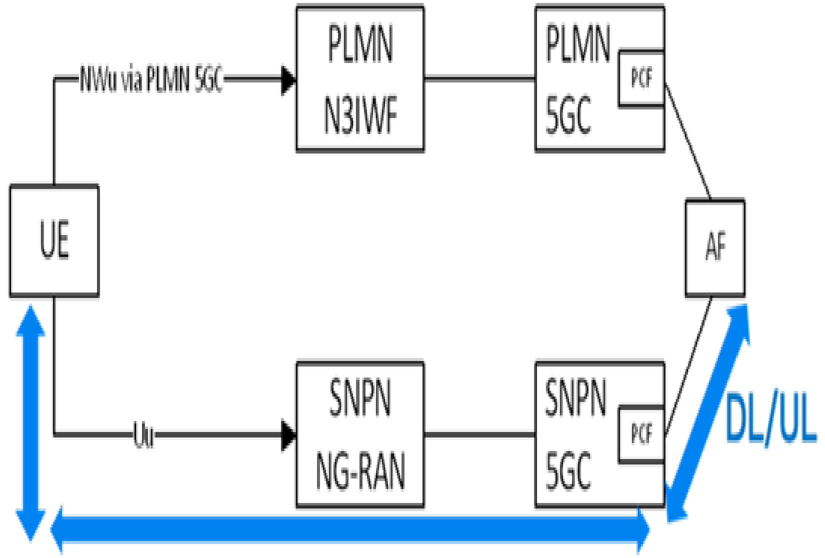


Figure 6.46.1-2. VIAPA traffic delivered over SNPN. The UE is connected to SNPN via Uu interface

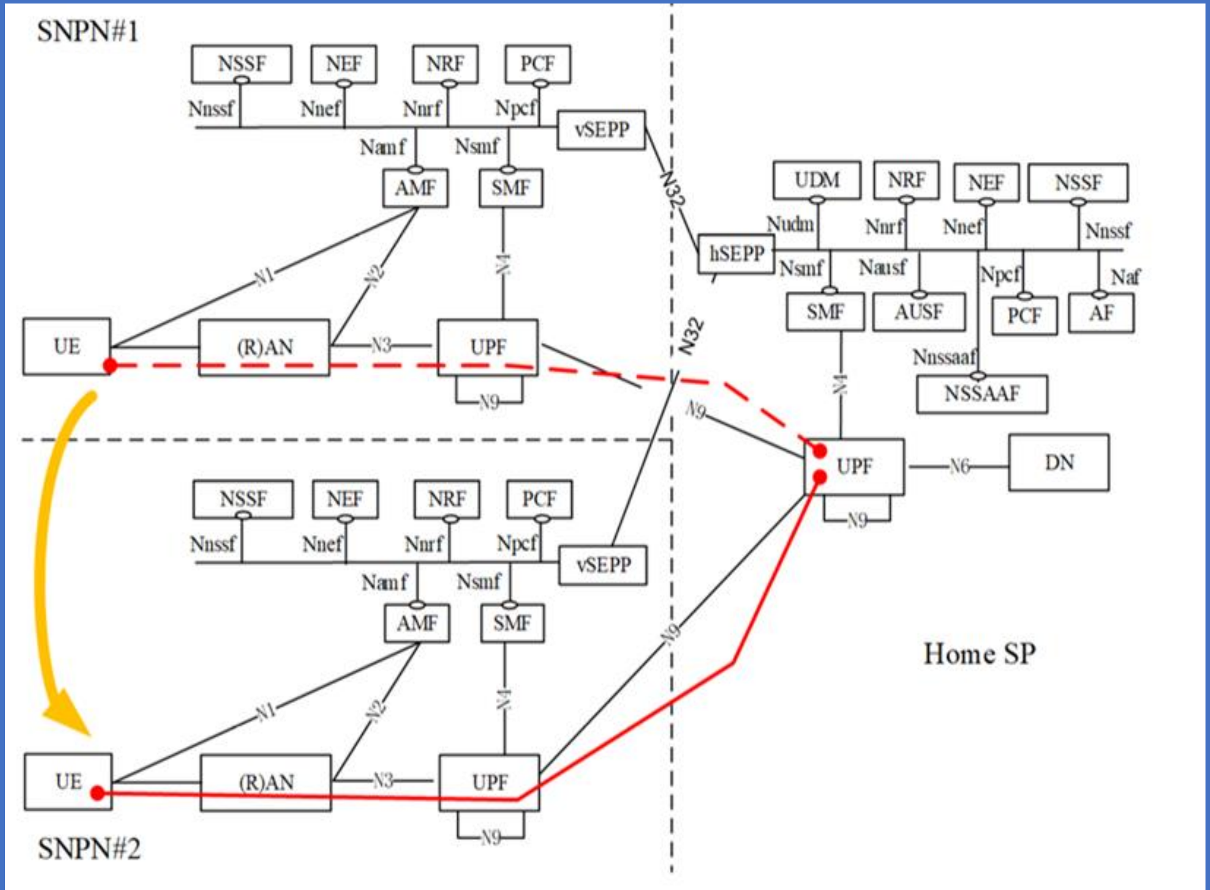


Figure 6.41.2-1: UE moving from SNPN#1 to SNPN#2 with PDU session anchored in the Home SP and Inter-PLMN like interworking between SNPN#2 and Home SP.

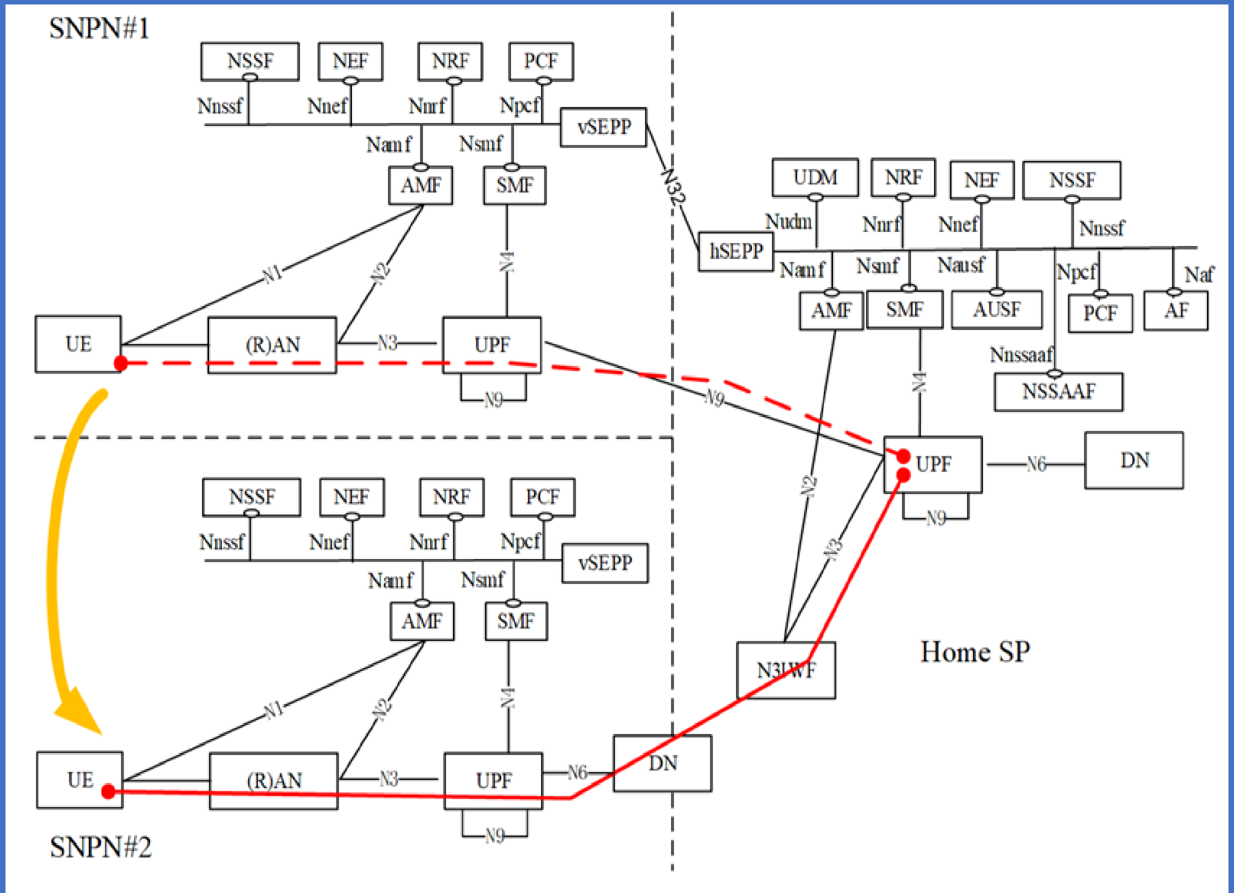


Figure 6.41.2-2: UE moving from SNPN#1 to SNPN#2 with PDU session anchored in the Home SP and N3IWF interworking between SNPN#2 and Home SP.

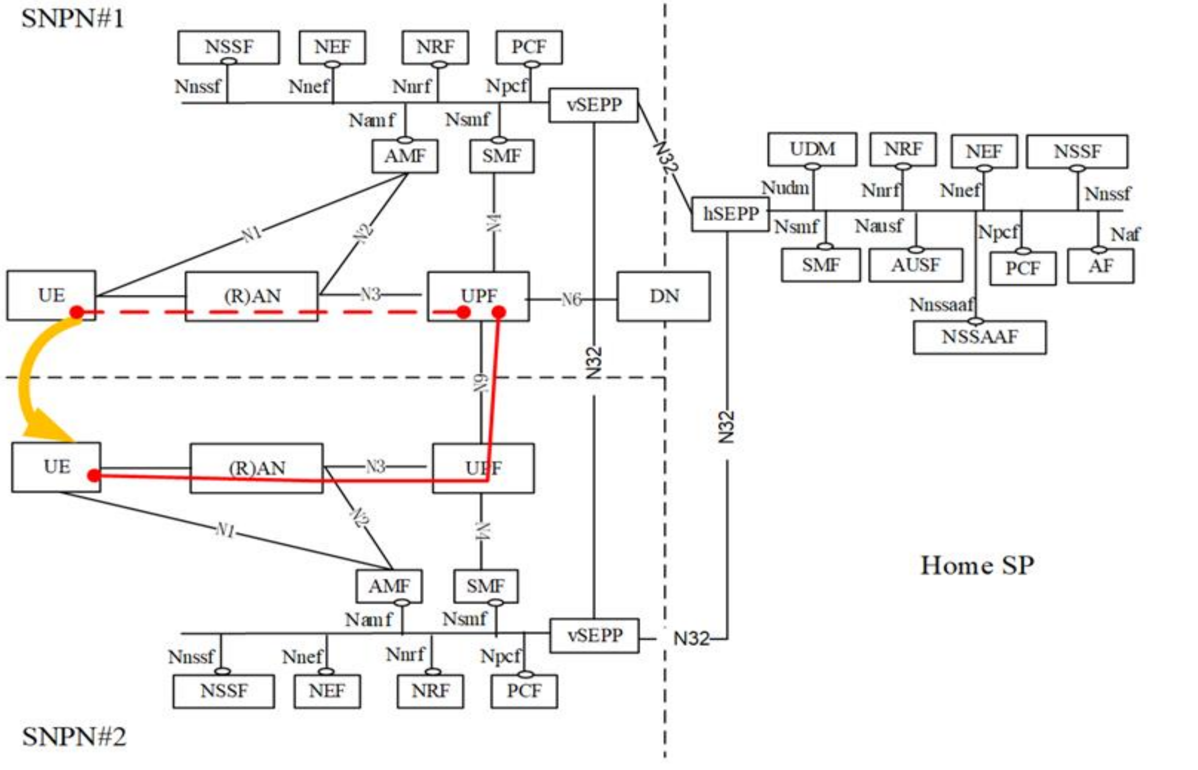


Figure 6.41.2-3: UE moving from SNPN#1 to SNPN#2 with PDU session anchored in the SNPN#1 and Inter-PLMN like interworking between SNPN#2 and SNPN#1.

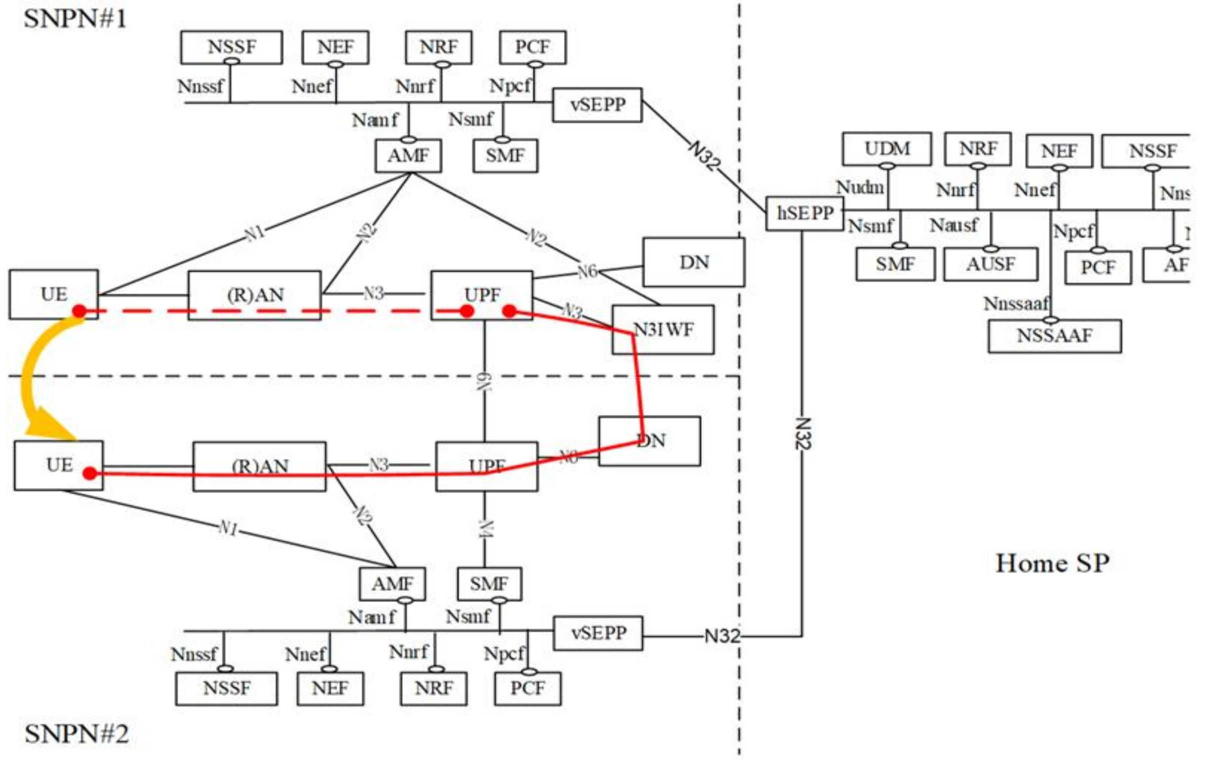


Figure 6.41.2-4: UE moving from SNPN#1 to SNPN#2 with PDU session anchored in the SNPN#1 and N3IWF interworking between SNPN#2 and SNPN#1.

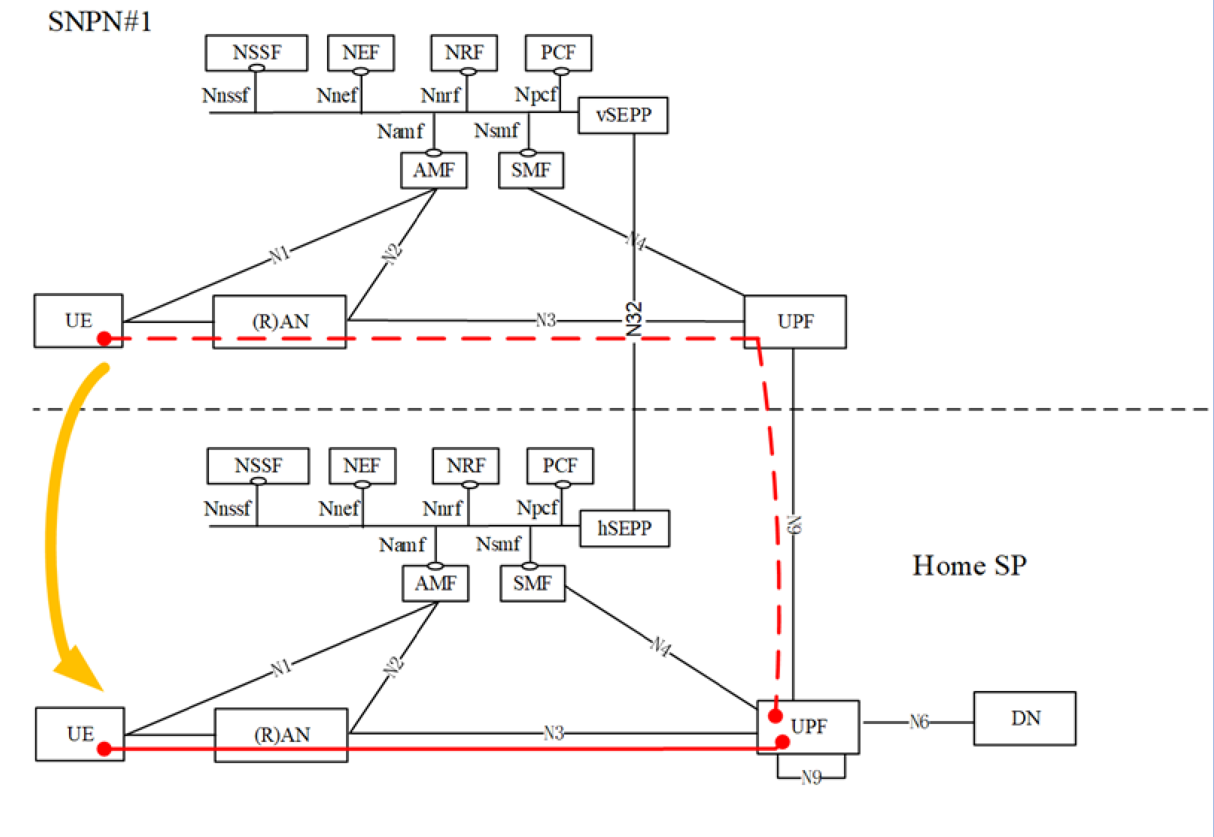


Figure 6.41.2-5: UE moving from SNPN#1 to Home SP with PDU session anchored in the Home SP.

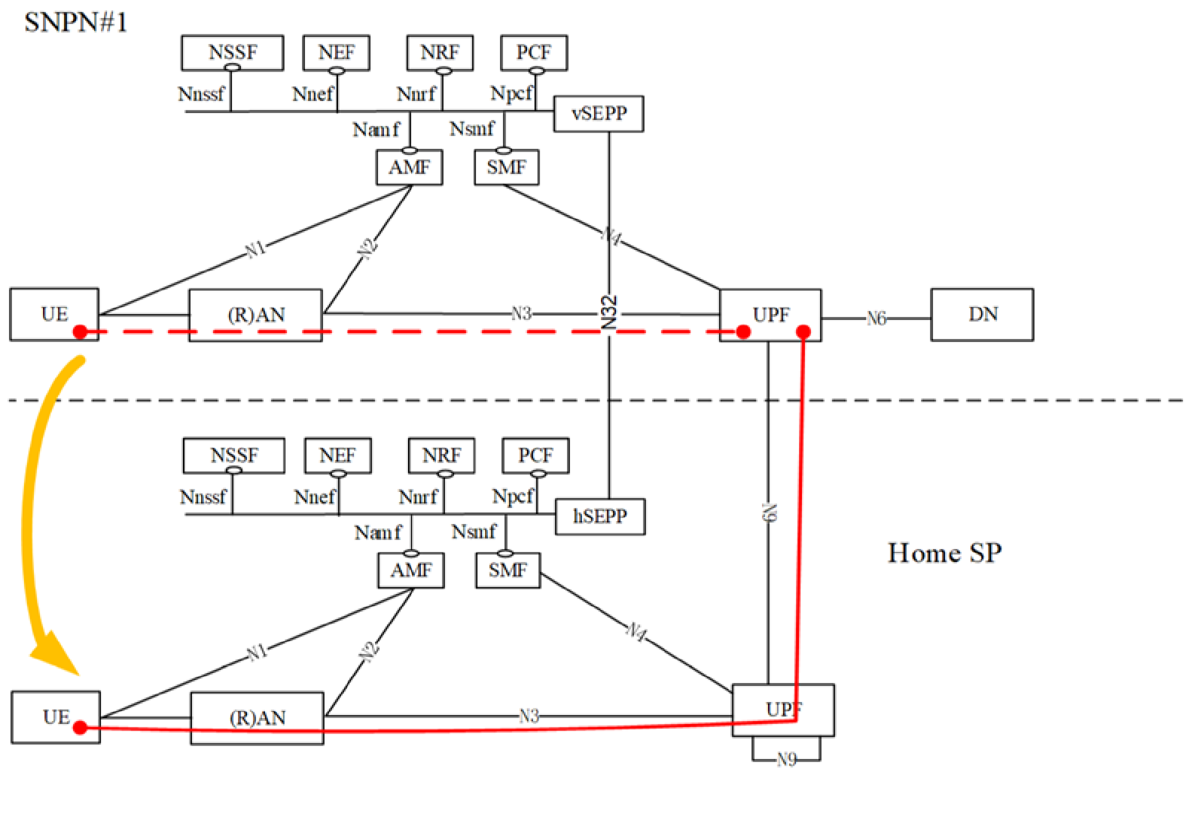


Figure 6.41.2-6: UE moving from SNPN#1 to Home SP with PDU session anchored in the SNPN#1.

Network selection - Re-using SNPN Access Mode (preferred)

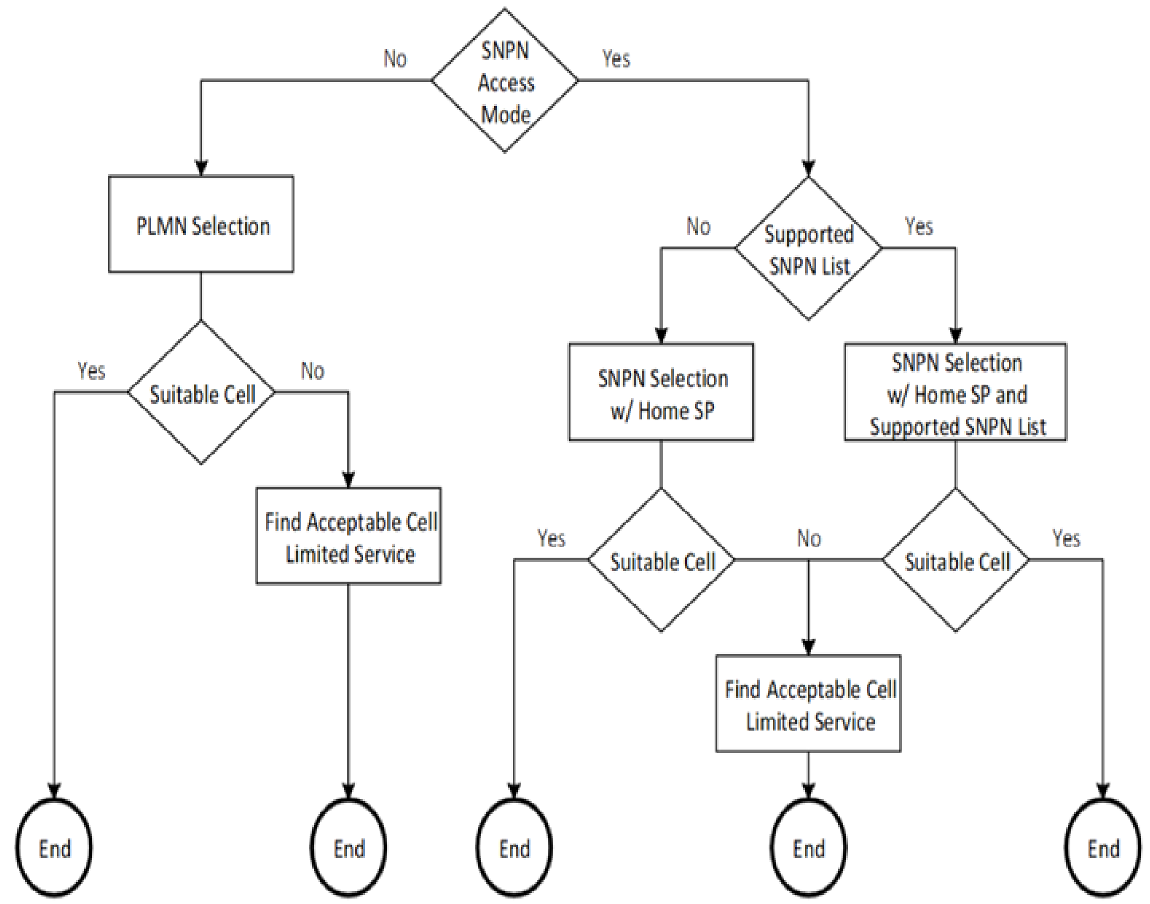


Figure 6.43.2.3.1-1: SNPN selection

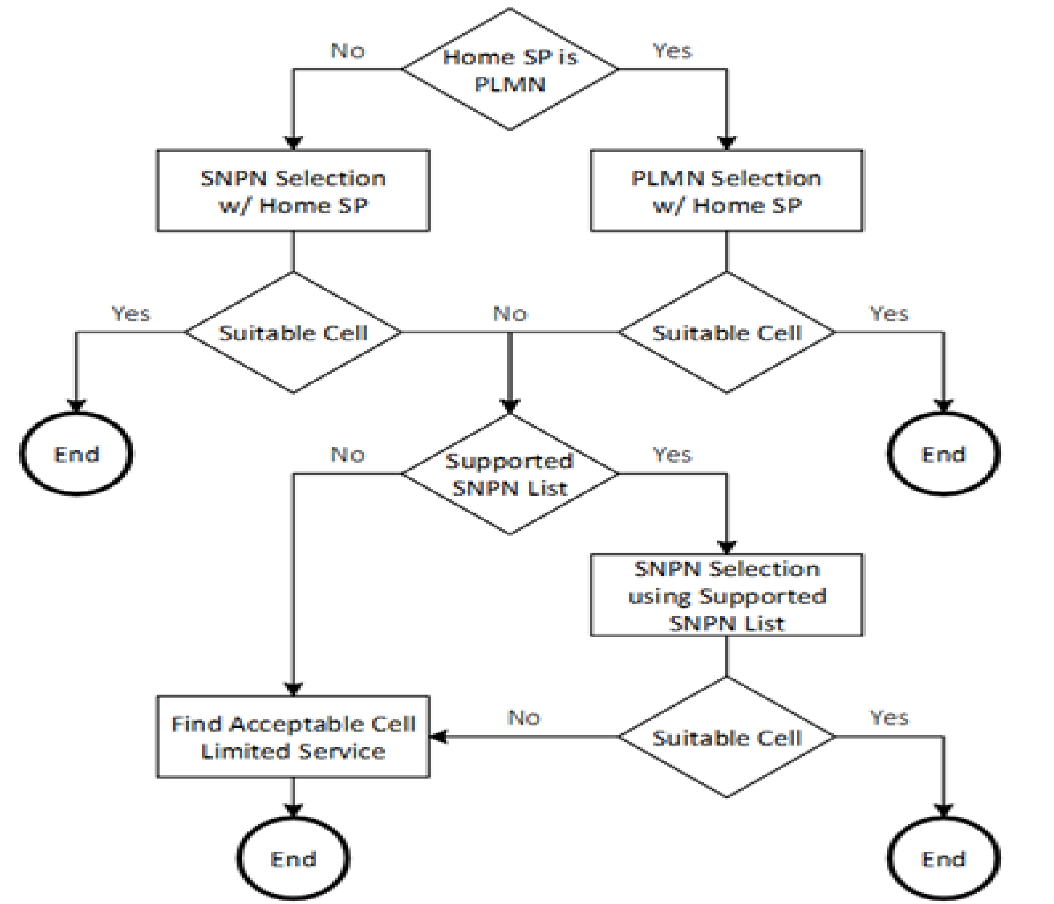


Figure 6.43.2.3.2-1: Network selection without SNPN Access Mode

Support of simultaneous active communication with SNPN and PLMN by using N3IWF

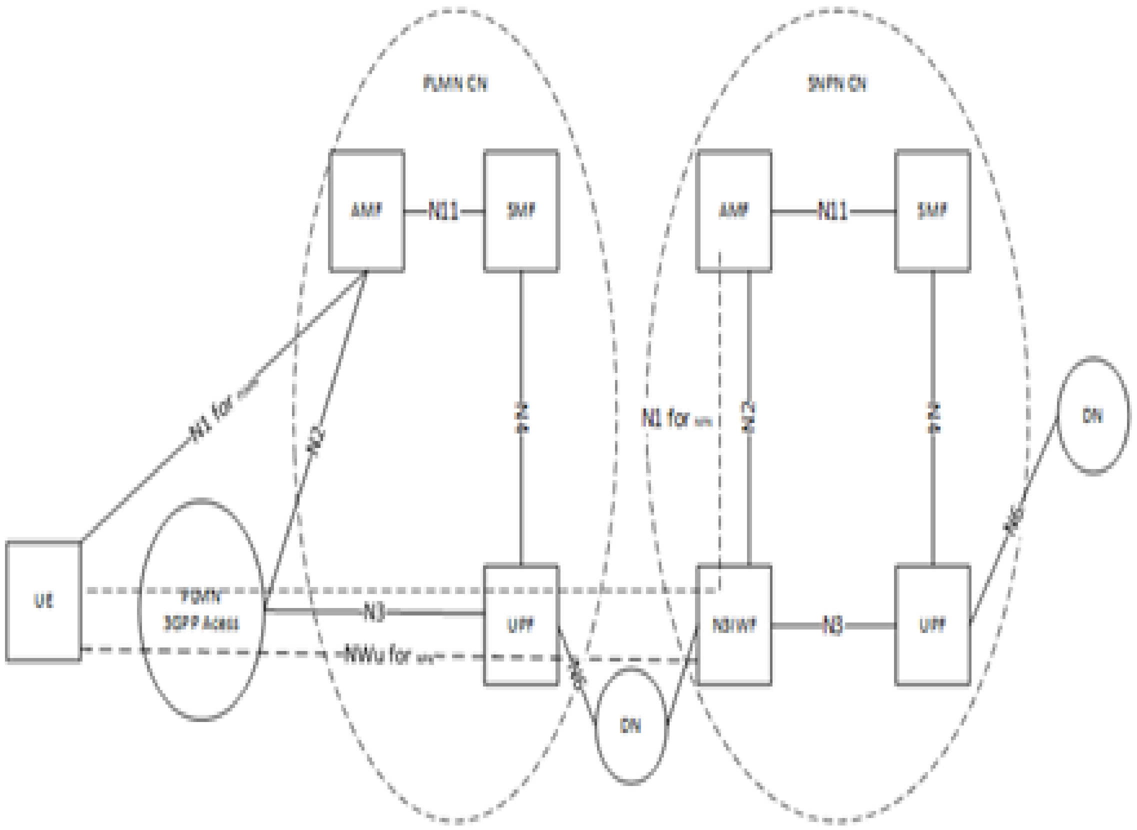


Figure 6.47.2-1: SNPN access via N3IWF using a PLMN PDU Session

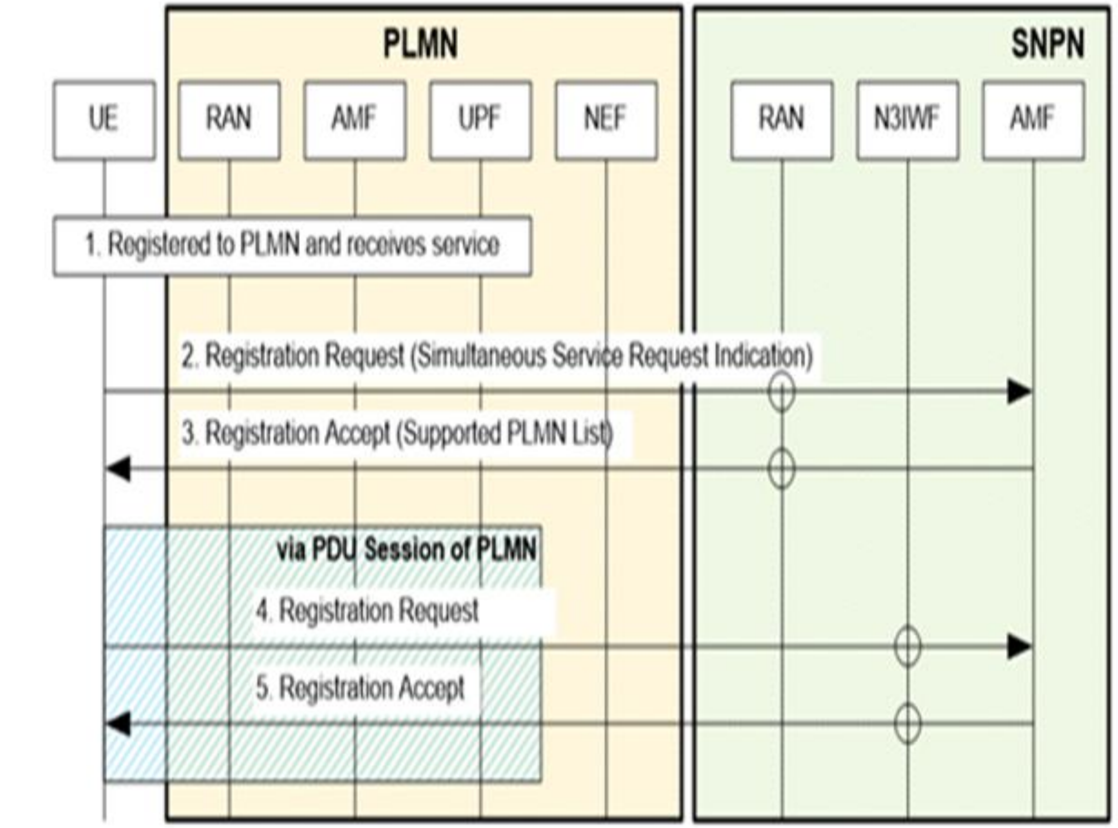


Figure 6.47.3-1: Procedure for simultaneous communication with SNPN and PLMN by using N3IWF

Solution #55: Paging in one network for another network

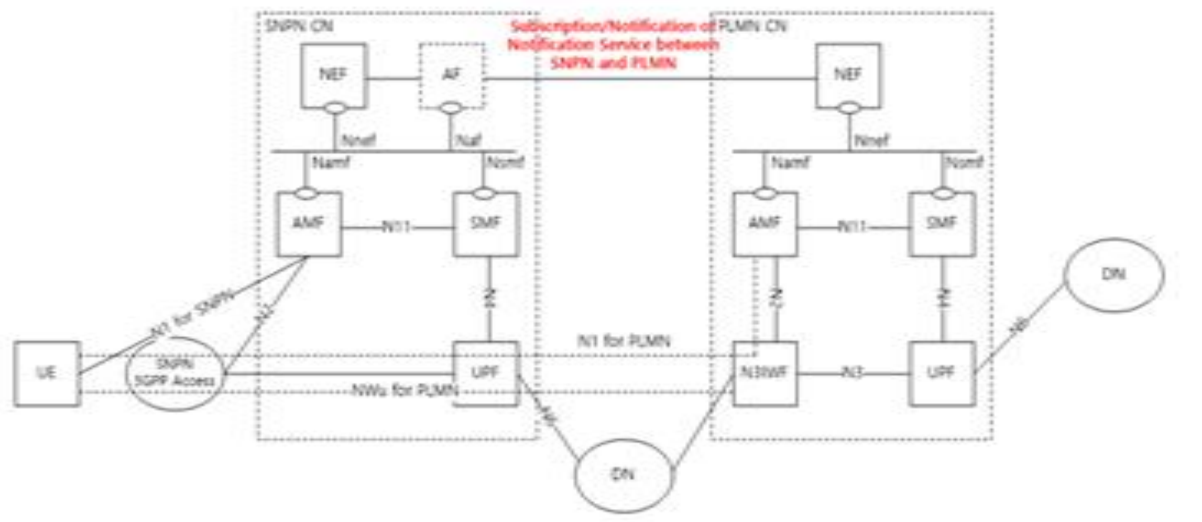


Figure 6.55.2.1-1: Access to PLMN services via Stand-alone Non-Public Network

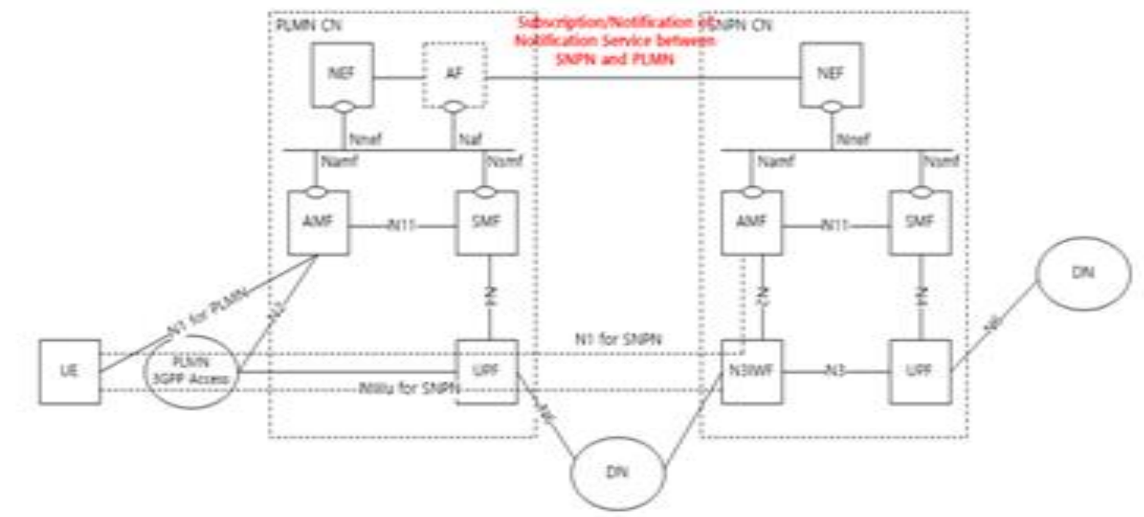


Figure 6.55.2.1-2: Access to Stand-alone Non-Public Network services via PLMN

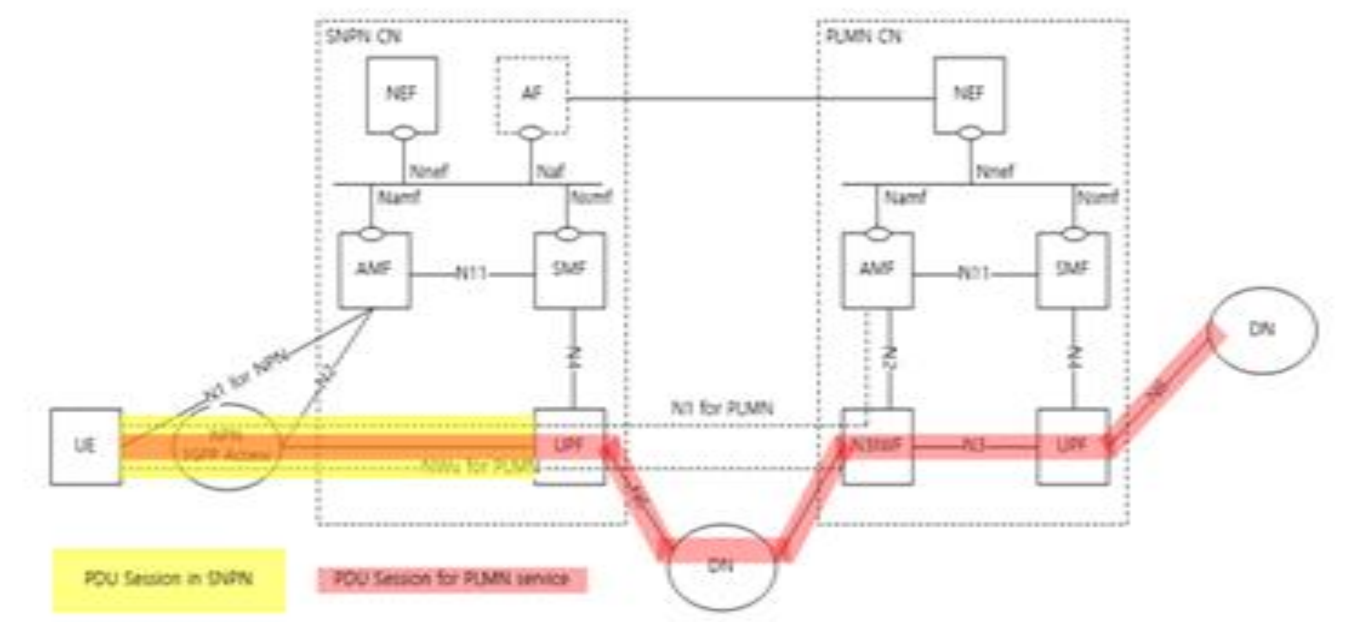


Figure 6.55.2.2-1: Access to PLMN service via SNPN

Ref.: 3GPP, Rel. 17

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			

Ref.: 3GPP, Rel. 17

	Enhanced Access & Support for Network Slice Configurations to UCs		
Nr Use Cases (UCs)	#1 When there is a Restriction of Network Slice (SST) to e.g., certain Frequency Bands/Sub Bands, RATs, Geographical Areas, Networks & Applications	#2 When a UE has a Subscription to Multiple Network Slices & these Network Slices are deployed for e.g., Different Frequency Bands/Sub Bands, RATs, Geographical Area & Applications	#3 When there is a Preference or Prioritization for a Network Slice (SST) over other Network Slices (SST) e.g. when there are conflicting constraints on Network Slice (SST) Availability.
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			

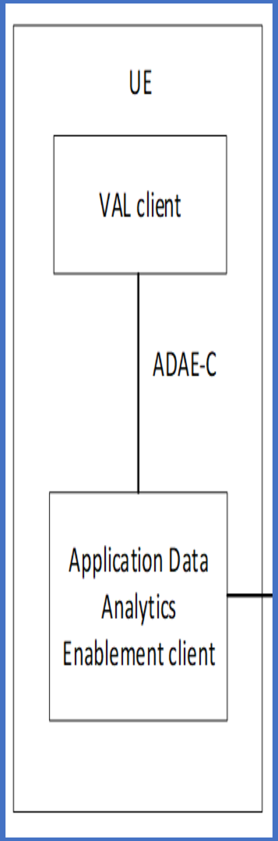
Ref.: 3GPP, Rel. 17 & 18

IIoT Solutions to IIoT Key Issues

	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				

Ref.: 3GPP, Rel. 17

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



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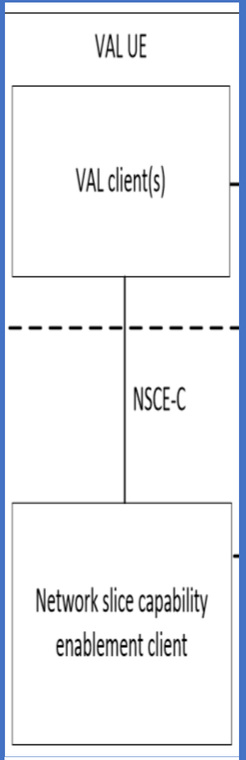

Fig.: NSCE-C

+

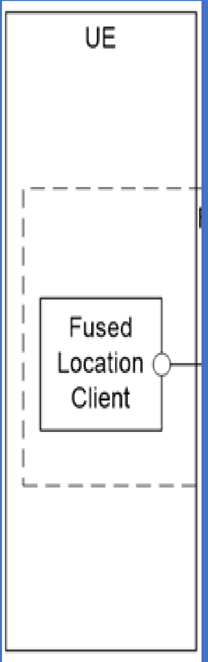

Fig. FLC Funct. In the UE

+

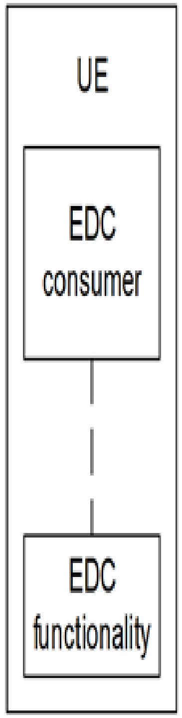

Fig. EDC Funct. in the UE

+

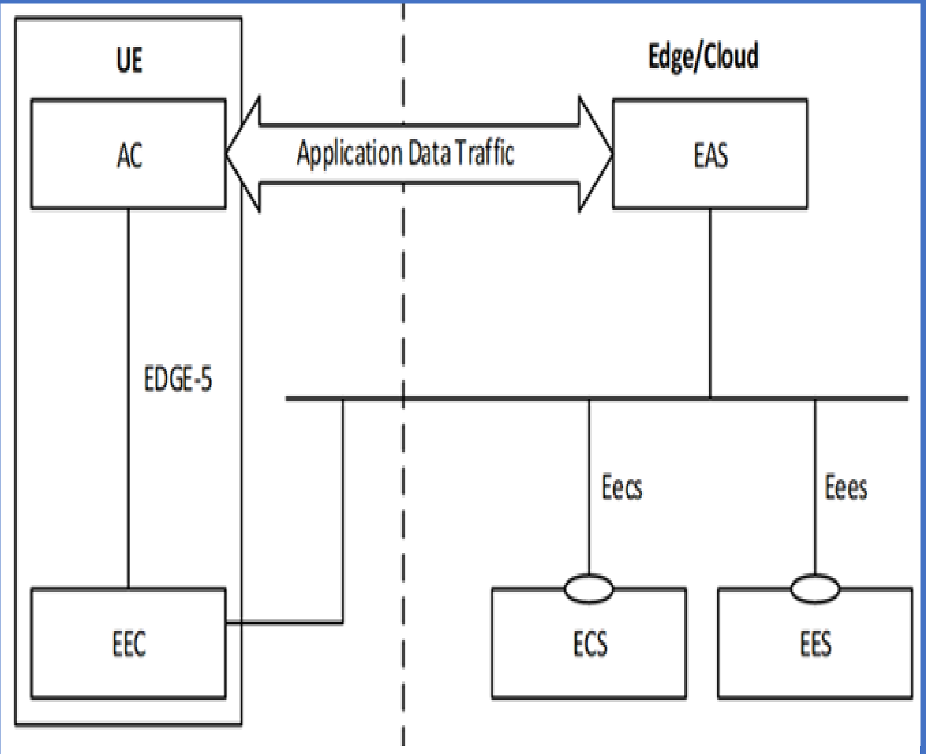

Fig. Archit. For Enabling Edge Applic. - Service-based Represent

Ref.: 3GPP, Rel. 17

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

Table 6.22.2.2-1: Access Identities

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 6.22.2.3-1: Access Categories

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 UE to a NB-IOT cell connected to 5GC when the UE is authorized to send exception data.

5G NFs SFC - Service Function Chaining

The study targets the use of Traffic Steering Concept, e.g. defined by 3GPP (FMSS) and SFC mechanisms defined in IETF when applicable.

Especially the study aims at reusing User Plane (UP) mechanisms

(e.g. VXLAN, NSH, GENEVE, GRE, VLAN, etc.) defined at IETF to support SFC, as applicable.

Solutions shall build on the 5G System Architectural Principles including Flexibility and Modularity for newly introduced functionalities.

- 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), this key issue will study Solution on:

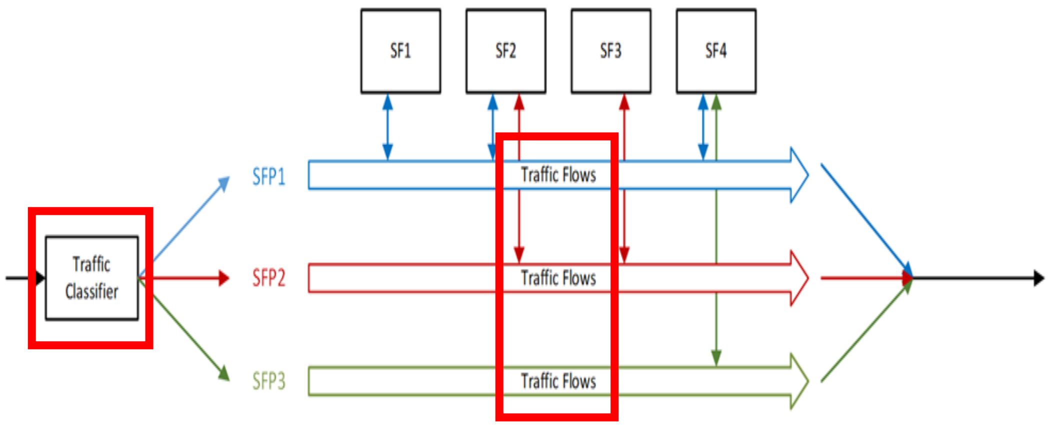

Figure 4-1: Illustration of the service function chaining concepts

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

Ref.: 3GPP, Rel. 16

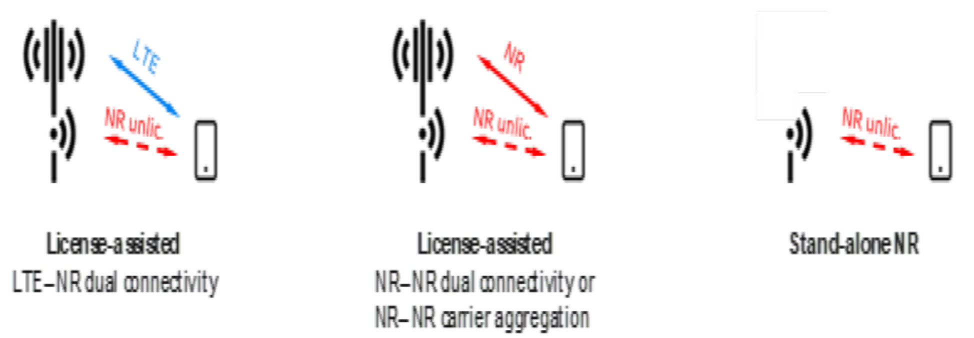

Fig. 3.10. License-assisted (left and middle) and stand-alone (right) operation of NR in unlicensed spectra.

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

This Scenario targets NPN

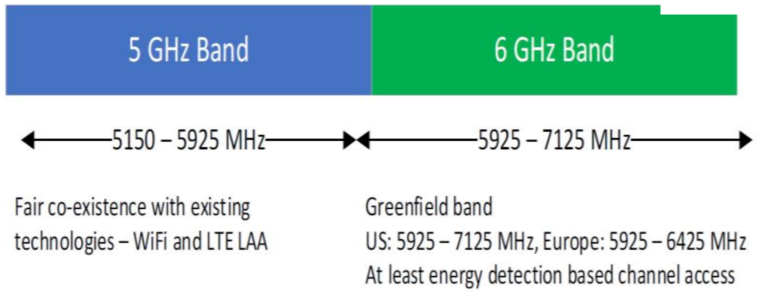

Fig. 3.9. Spectrum priorities for NR-U.

- In 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.

- **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).**
- **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.: 5GA 2021

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:

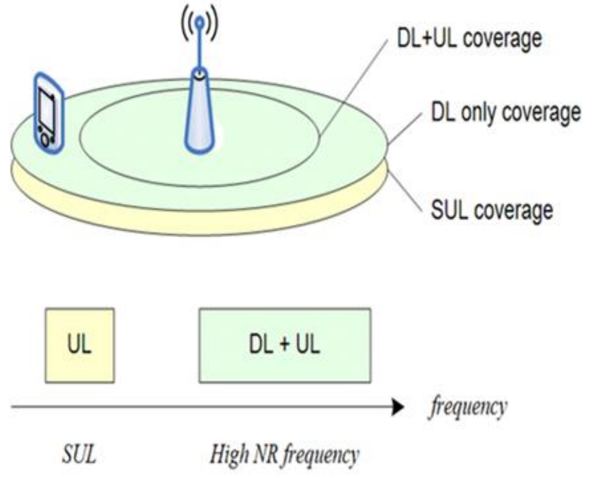

Figure B.1-1: Example of Supplementary Uplink

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 Enhanced Access and Support Mapping Configurations to Use Cases

	Enhanced Access & Support for Network Slice Configurations to UCs		
Nr Use Cases (UCs)	#1 When there is a Restriction of Network Slice (SST) to e.g., certain Frequency Bands/Sub Bands, RATs, Geographical Areas, Networks & Applications	#2 When a UE has a Subscription to Multiple Network Slices & these Network Slices are deployed for e.g., Different Frequency Bands/Sub Bands, RATs, Geographical Area & Applications	#3 When there is a Preference or Prioritization for a Network Slice (SST) over other Network Slices (SST) e.g. when there are conflicting constraints on Network Slice (SST) Availability.
1			
2			
3			
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13			

Ref.: 3GPP, Rel. 18

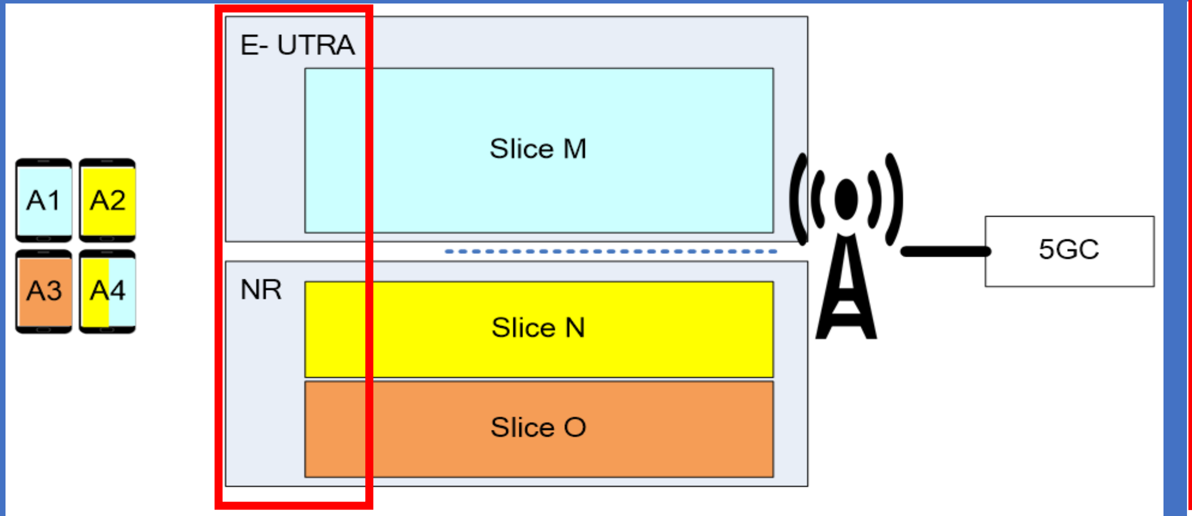


Figure 5.4.2-1 Initial condition

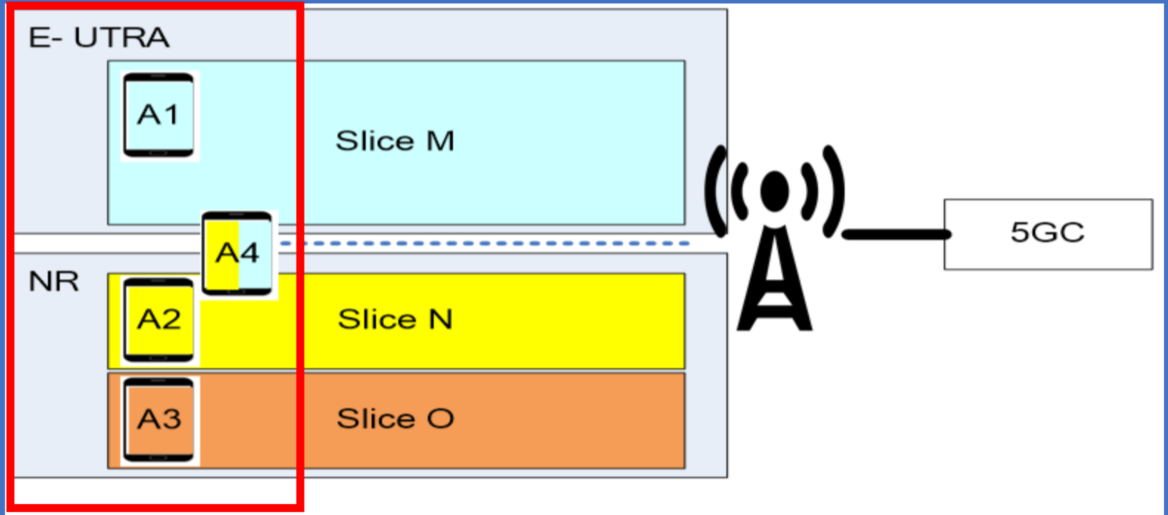


Figure 5.4.4-1 End result

For a normal working day at the office, Rama's UE selects slice M and Krishna's UE selects slice N based on their preferences.

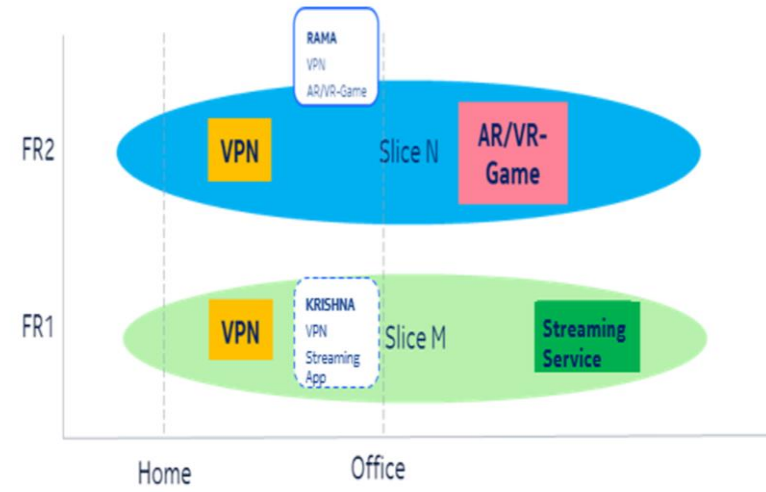


Figure 5.8.3-1: Applications preferred network slices for Rama and Krishna during Workdays (Working Hours)

Both return to their homes after office hours. Both Rama's UE and Krishna's UE select slice M based on their preferences.

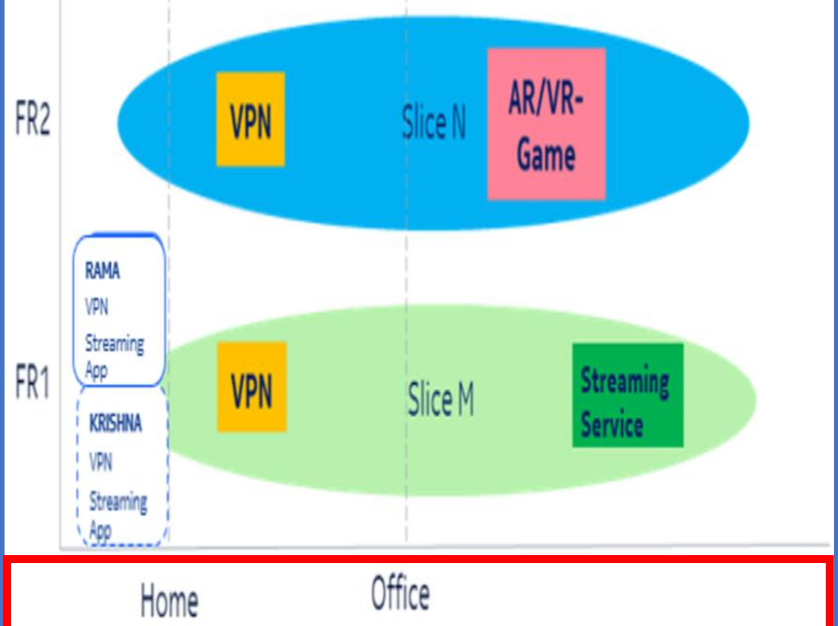


Figure 5.8.3-2: Applications preferred network slices for Rama and Krishna during Evenings (off-Working Hours)

During a WFH Day for Rama, he changes his profile setting to use 'WFH Profile'. While Krishna goes to office as usual. Rama's UE stays on slice M instead of switching to Slice N while Krishna's UE selects slice M as usual at the office.

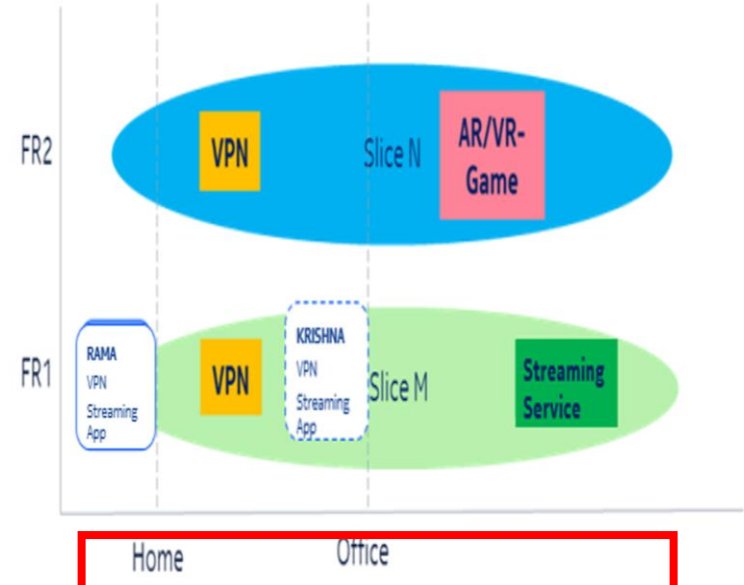


Figure 5.8.3-3: WFH Scenario for Rama and normal work day for Krishna.

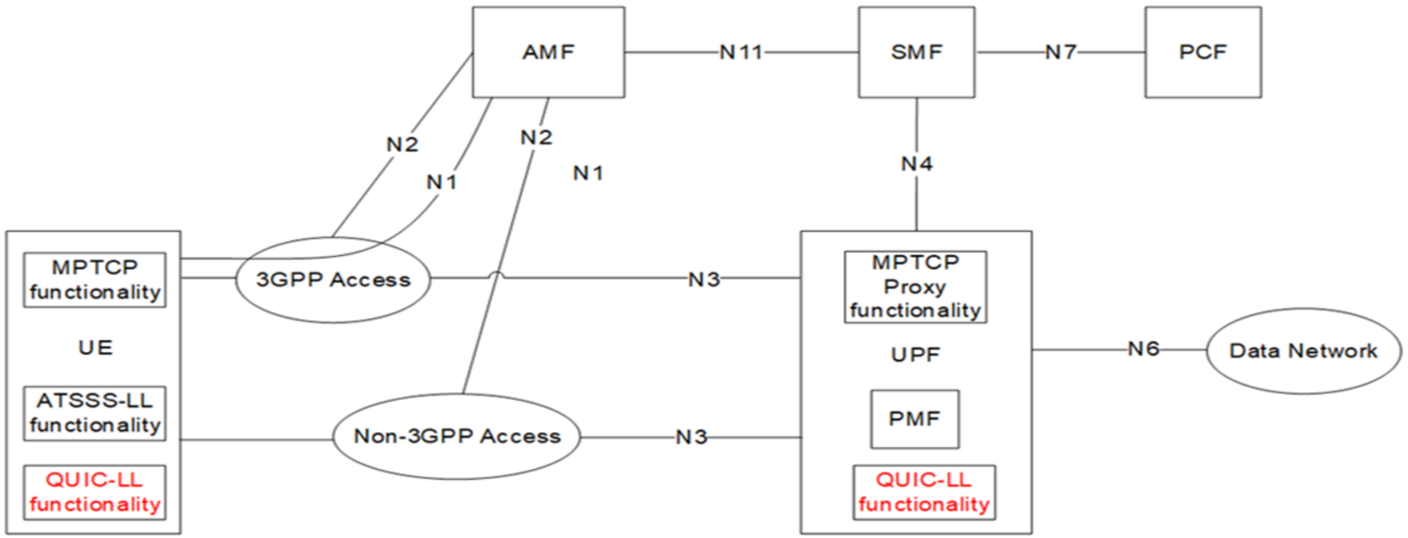


Fig. Reference Arch. for ATSSS using QUIC-LL

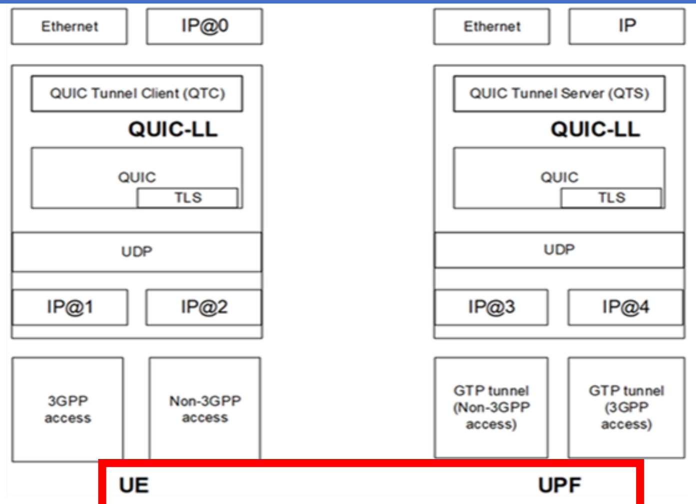


Fig. Protocol Stack for QUIC-LL

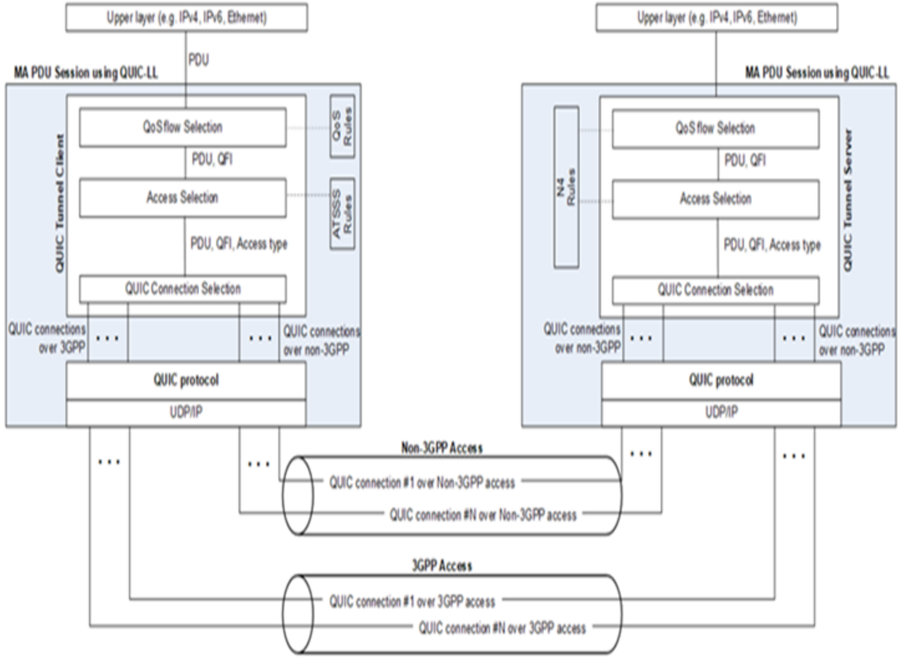


Figure 6.1.1-1: Model of MA PDU Session using QUIC-LL

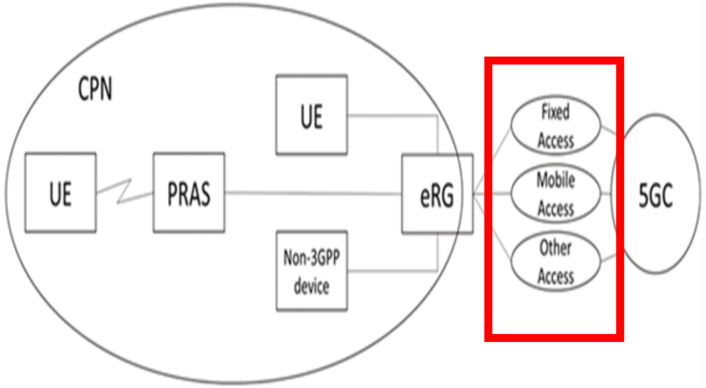


Fig. Customer Premises Network (CPN) connected to 5G Core (5GC)

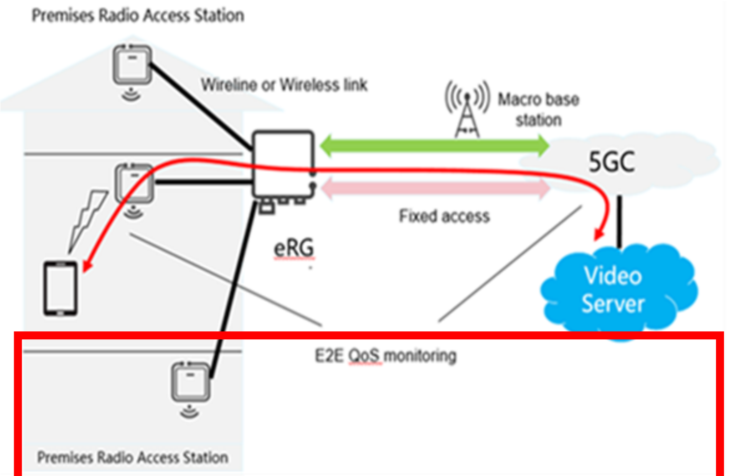


Fig. 5G CPN (Customer Premises Network) E2E QoS monitoring

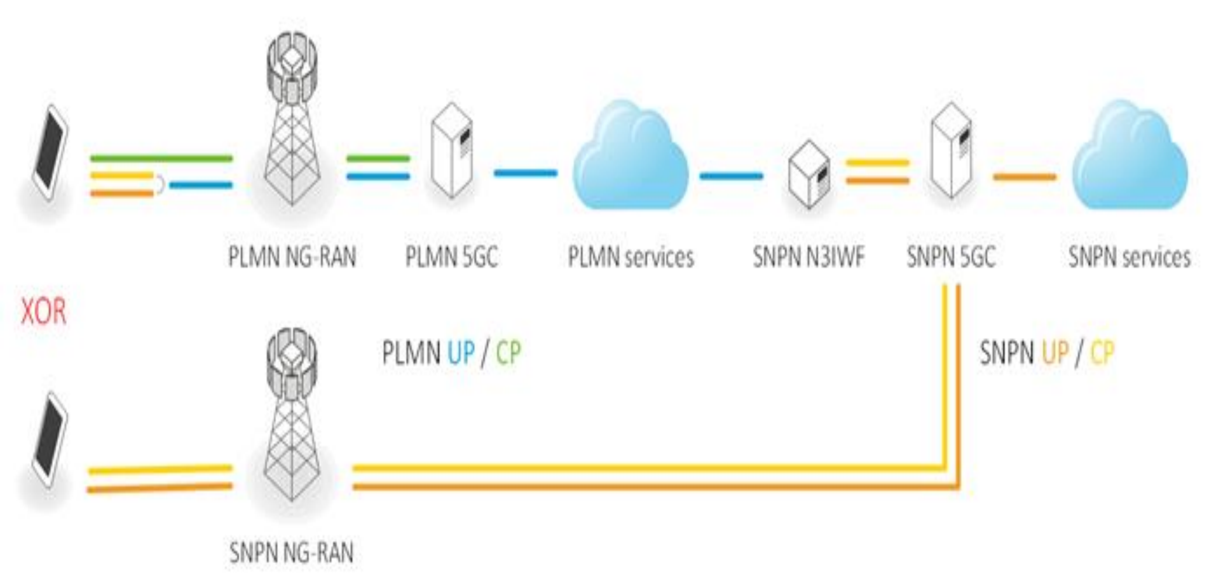


Figure 6.15.2.1-2: Distinct accesses to an SNPN for a single radio UE

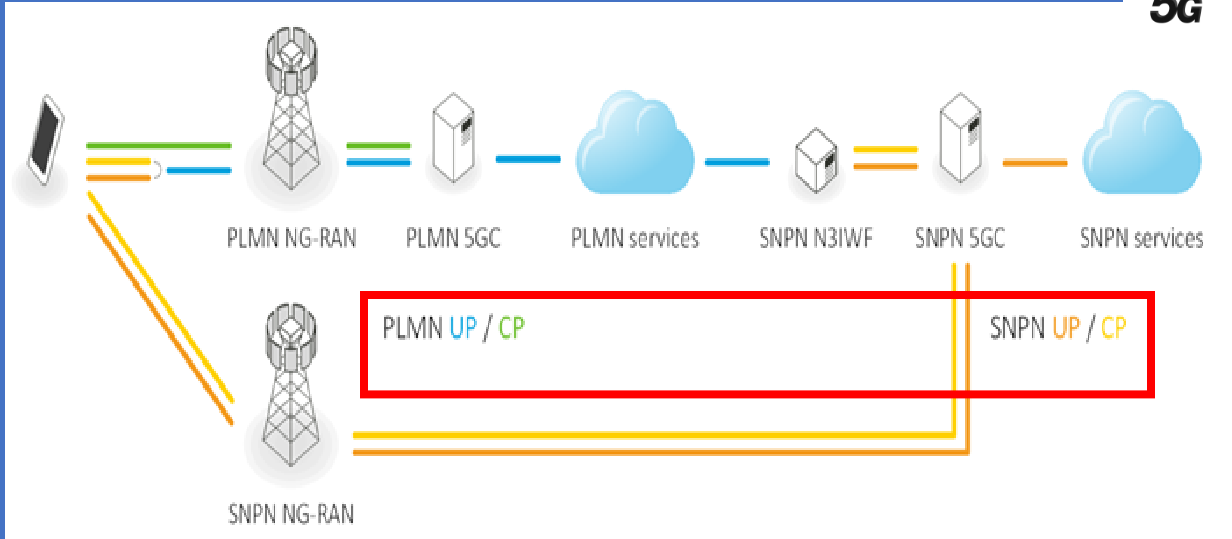


Figure 6.15.2.1-1: Concurrent accesses to an SNPN for Session and Service Continuity (Dual-radio UE)

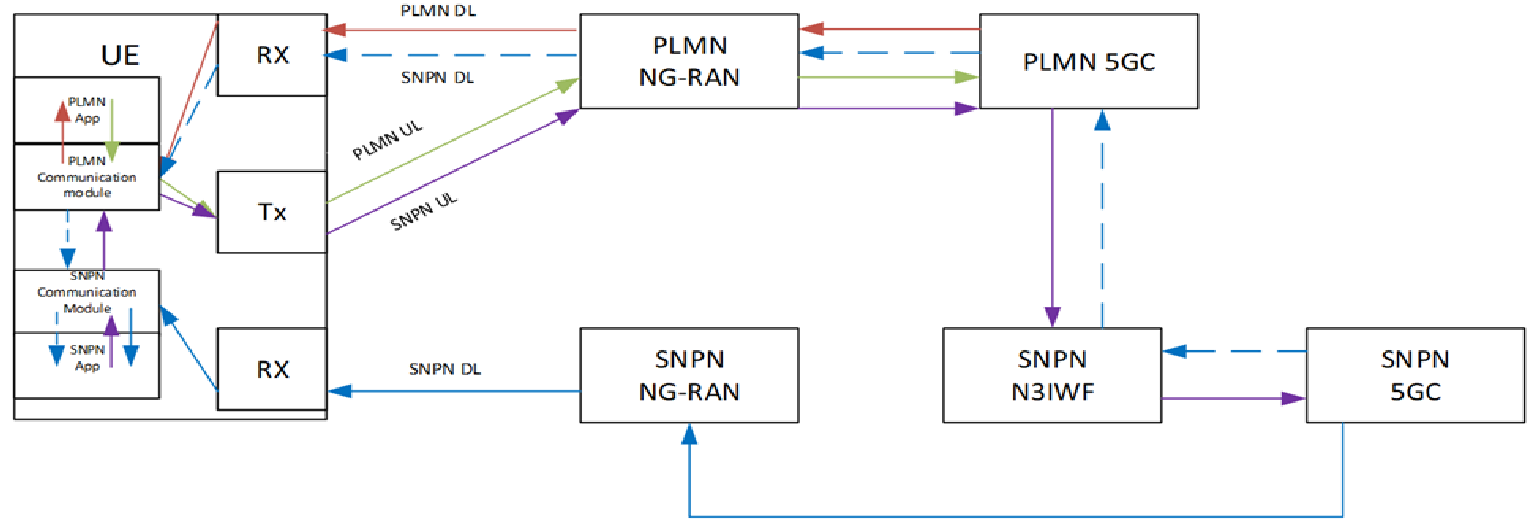


Figure 6.18.2.2-1: Architectural overview of a 2Rx/1Tx dual radio UE simultaneously connected to a SNPN and a PLMN

General performance requirements - Video and Audio Production Applications

Table: Performance Requirements for Airborne Base Stations for NPN

Profile	# of active UEs	UE Speed	Service Area	E2E latency	Packet error rate (Note 1)	Data rate UL	Data rate DL
NPN ground to air UHD up Link	10	500 km/h	700 km2 x 6000 m (Note 2)	40 ms	10^{-8} UL 10^{-7} DL	100 Mbit/s	20 Mbit/s
NPN ground to air HD up link	10	500 km/h	700 km2 x 6000 m (Note 2)	40 ms	10^{-8} UL 10^{-7} DL	80 Mbit/s	20 Mbit/s
NPN air to ground UHD down Link	2	500 km/h	700 km2 x 6000 m (Note 2)	40 ms	10^{-7} UL 10^{-8} DL	20 Mbit/s	100 Mbit/s
NPN air to ground HD down link	2	500 km/h	700 km2 x 6000 m (Note 2)	40 ms	10^{-7} UL 10^{-8} DL	20 Mbit/s	80 Mbit/s
NPN radio Camera UHD	10	200 km/h	1 km^2	3 ms	10^{-8} UL 10^{-7} DL	100 Mbit/s	20 Mbit/s
NPN radio camera HD	10	200 km/h	1 km^2	3 ms	10^{-8} UL 10^{-7} DL	80 Mbit/s	20 Mbit/s

NOTE 1: Packets that do not conform with the end-to-end latency are also accounted as error. The packet error rate requirement is calculated considering 1500 B packets, and 1 packet error per hour is $10^{-5}/(3*x)$, where x is the data rate in Mbps.

NOTE 2: 6000 m = height but in a cone formation (i.e. ground coverage with a circle of diameter 30 KM)

Table: Performance Requirements of low-latency Periodic Deterministic Audio Transport Service in Presentation Use Cases

Profile	# of active UEs	UE Speed	Service Area	E2E latency (Note 1)	Transfer interval (Note 1)	Packet error rate (Note 2, Note 3)	Data rate UL	Data rate DL
Ad hoc	20	5 km/h	300 m x 300 m	4 ms	1 ms	10^{-5}	200 kbit/s	-
	8	stationary	300 m x 300 m	4 ms	1 ms	10^{-5}	-	200 kbit/s
Campus	1000	5 km/h	2 km x 2 km	4 ms	1 ms	10^{-5}	200 kbit/s	-
Conference	10	5 km/h	100 m x 100 m	4 ms	1 ms	10^{-5}	1.5 Mbit/s	-
	4	stationary	100 m x 100 m	4 ms	1 ms	10^{-5}	-	1.5 Mbit/s
Lecture room	4	5 km/h	10 m x 10 m	4 ms	1 ms	10^{-5}	50 kbit/s	-
	2	stationary	10 m x 10 m	4 ms	1 ms	10^{-5}	-	50 kbit/s

NOTE 1: Transfer interval refers to periodicity of the packet transfers. It has to be constant during the whole operation. The value given in the table is a typical one, however other transfer intervals are possible as long as the end-to-end latency is ≤ (5 ms – Transfer interval).

NOTE 2: Packet error rate is related to a packet size of (Transfer interval × data rate). Packets that do not conform with the end-to-end latency are also accounted as error.

NOTE 3: The given requirement for a packet error rate assumes a uniform error distribution. The requirement for packet error rate is stricter if packet errors occur in bursts.

Ref.: 3GPP, Rel. 17

5G ACT & ACR (Application Context Transfer & Application Context Relocation for Service Continutiy T-EAS & S-EAS

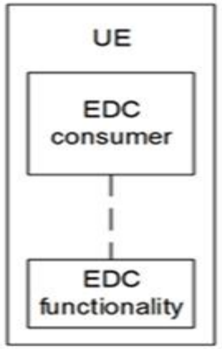


Fig. EDC Funct. in the UE

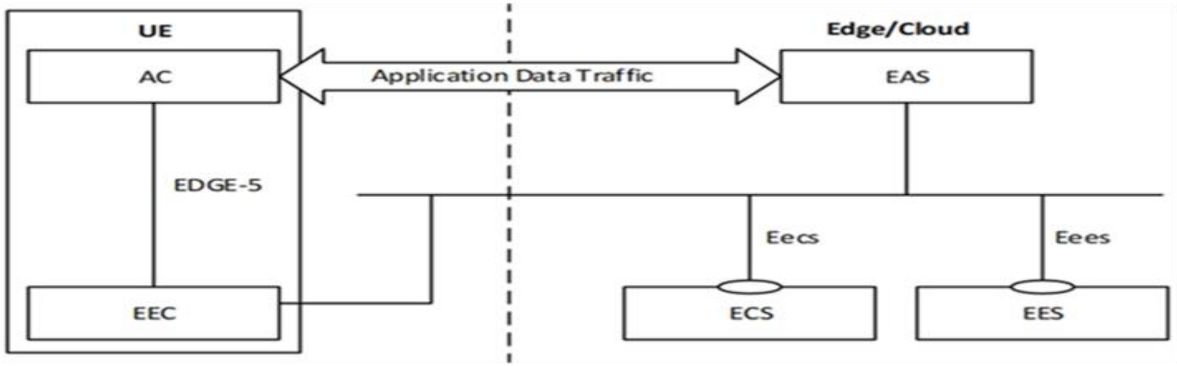


Fig. Archit. For Enabling Edge Applic. - Service-based Represent

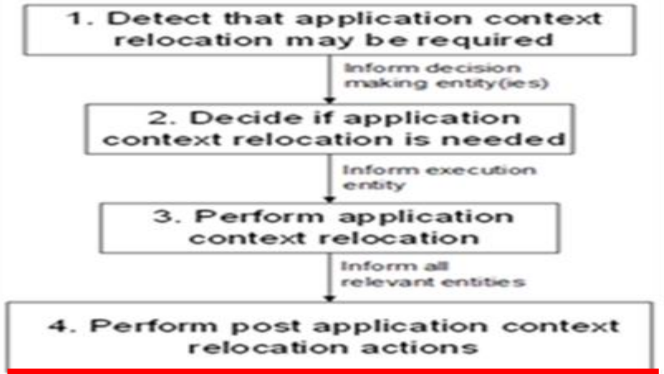


Fig. High level overview of ACR (Application Context Relocation)

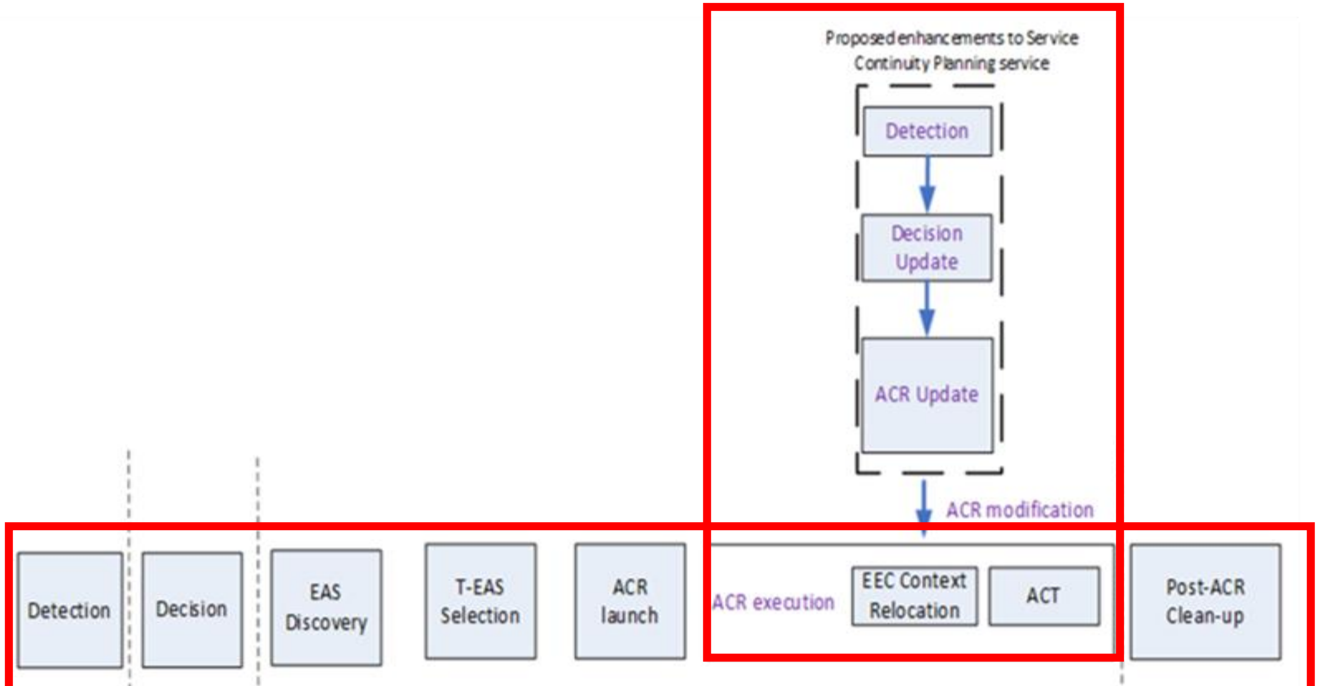


Fig. High-level of proposed ACR update in Service Continuity Planning Enhancement

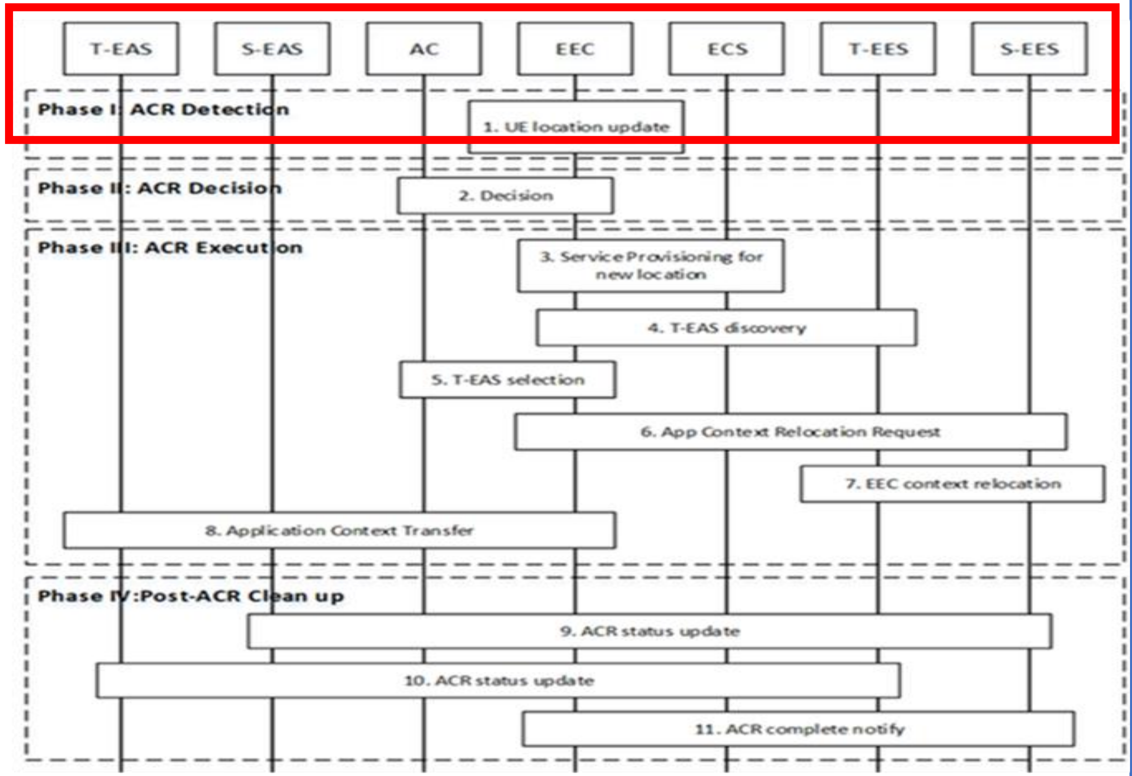


Fig. ACR initiated by the EEC & AC

Application Function (AF) influence on Traffic Routing

The content of this clause applies to :

- Non-Roaming and to
- LBO deployments

i.e. to cases where the involved entities (AF, PCF, SMF, UPF) belong to

- the Serving PLMN or
- AF belongs to a 3rd Party with which the Serving PLMN has an agreement.

AF influence on traffic routing does not apply in the case of Home Routed deployments. PCF shall not apply AF requests to influence traffic routing to PDU Sessions established in Home Routed mode.

An AF may send requests to influence SMF routing decisions for traffic of PDU Session.

The AF requests may influence UPF (re)selection and (I-)SMF (re)selection and allow routeing user traffic to a local access to a Data Network (identified by a DNAI).

The AF may issue requests on behalf of applications not owned by the PLMN serving the UE.

Ref.3GPP TS 23 501 5G System Architect., Rel., 17, Dec 2021: 132 - 133

Table 5.6.7-1: Information element contained in AF request

Information Name	Applicable for PCF or NEF (NOTE 1)	Applicable for NEF only	Categor
Traffic Description	Defines the target traffic to be influenced, represented by the combination of DNN and optionally S-NSSAI, and application identifier or traffic filtering information.	The target traffic can be represented by AF-Service-Identifier, instead of combination of DNN and optionally S-NSSAI.	Mandatory
Potential Locations of Applications	Indicates potential locations of applications, represented by a list of DNAI(s).	The potential locations of applications can be represented by AF-Service-Identifier.	Conditional (NOTE 2)
Target UE Identifier(s)	Indicates the UE(s) that the request is targeting, i.e. an individual UE, a group of UE represented by Internal Group Identifier (NOTE 3), or any UE accessing the combination of DNN, S-NSSAI and DNAI(s).	GPSI can be applied to identify the individual UE, or External Group Identifier can be applied to identify a group of UE.	Mandatory
Spatial Validity Condition	Indicates that the request applies only to the traffic of UE(s) located in the specified location, represented by areas of validity.	The specified location can be represented by geographical area.	Optional
AF transaction identifier	The AF transaction identifier refers to the AF request.	N/A	Mandatory
N6 Traffic Routing requirements	Routing profile ID and/or N6 traffic routing information corresponding to each DNAI and an optional indication of traffic correlation.	N/A	Optional (NOTE 2)
Application Relocation Possibility	Indicates whether an application can be relocated once a location of the application is selected by the 5GC.	N/A	Optional
UE IP address preservation indication	Indicates UE IP address should be preserved.	N/A	Optional
Temporal Validity Condition	Time interval(s) or duration(s).	N/A	Optional
Information on AF subscription to corresponding SMF events	Indicates whether the AF subscribes to change of UP path of the PDU Session and the parameters of this subscription.	N/A	Optional
Information for EAS IP Replacement in 5GC	Indicates the Source EAS identifier and Target EAS identifier, (i.e. IP addresses and port numbers of the source and target EAS).	N/A	Optional
User Plane Latency Requirement	Indicates the user plane latency requirements	N/A	Optional
Information on AF change	N/A	Indicates the AF instance relocation and relocation information.	Optional
Indication for EAS Relocation	Indicates the EAS relocation of the application(s)	N/A	Optional
Indication for Simultaneous Connectivity over the source and target PSA at Edge Relocation	Indicates that simultaneous connectivity over the source and target PSA should be maintained at edge relocation and provides guidance to determine when the connectivity over the source PSA can be removed.	N/A	Optional

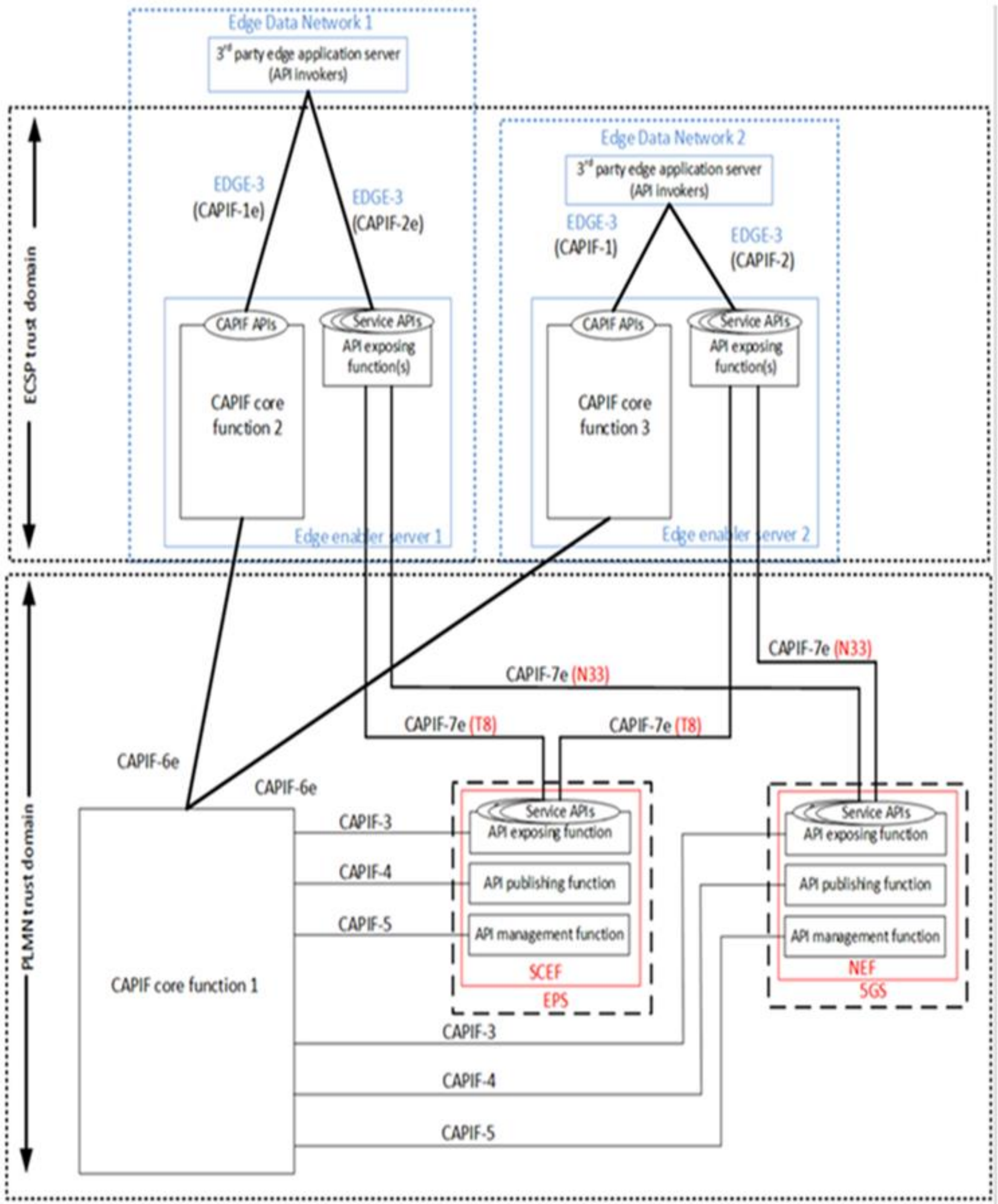


Fig. EES supporting Distributed CAPIF Functions

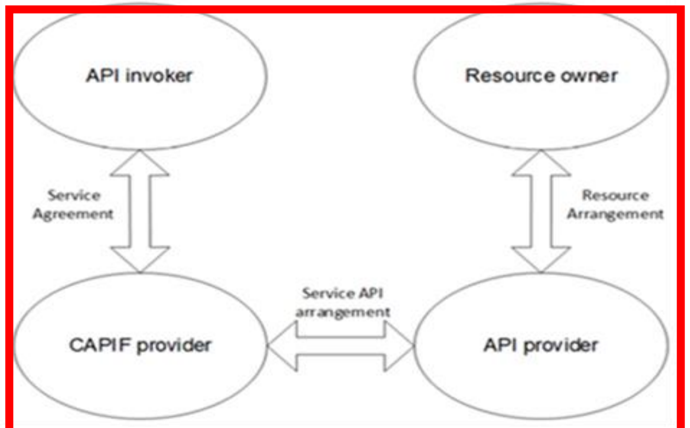


Fig. Business Relationship in SNA

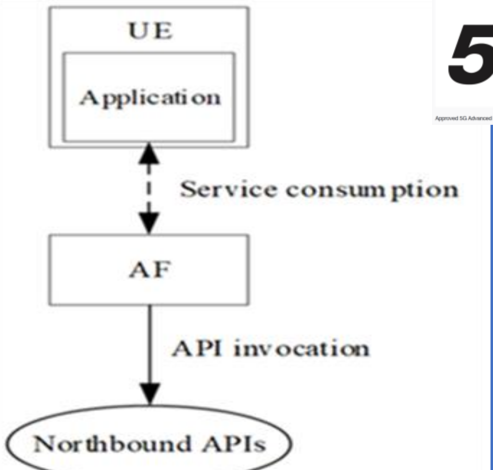


Fig. AF-originated API Invocation

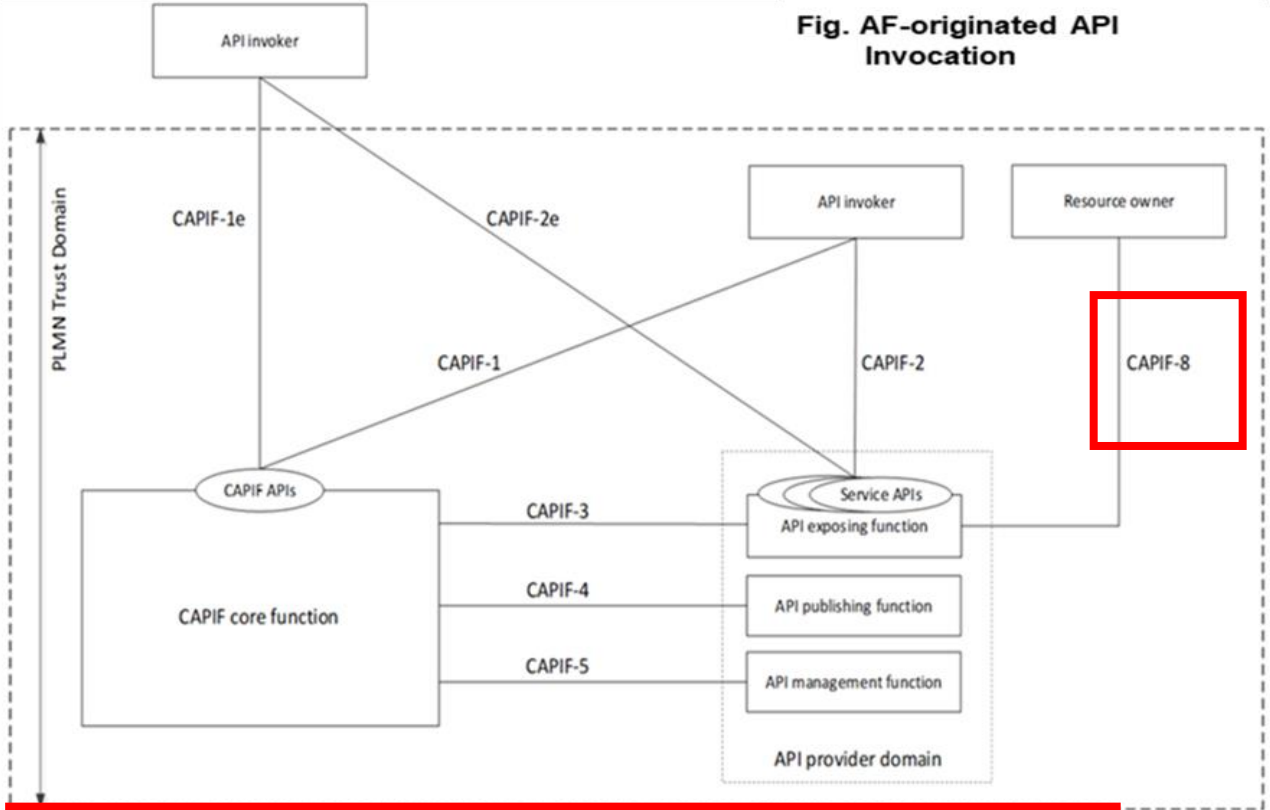


Fig. CAPIF AEF (API Expos. Funct.) for obtaining User Consent via CAPIF-8

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

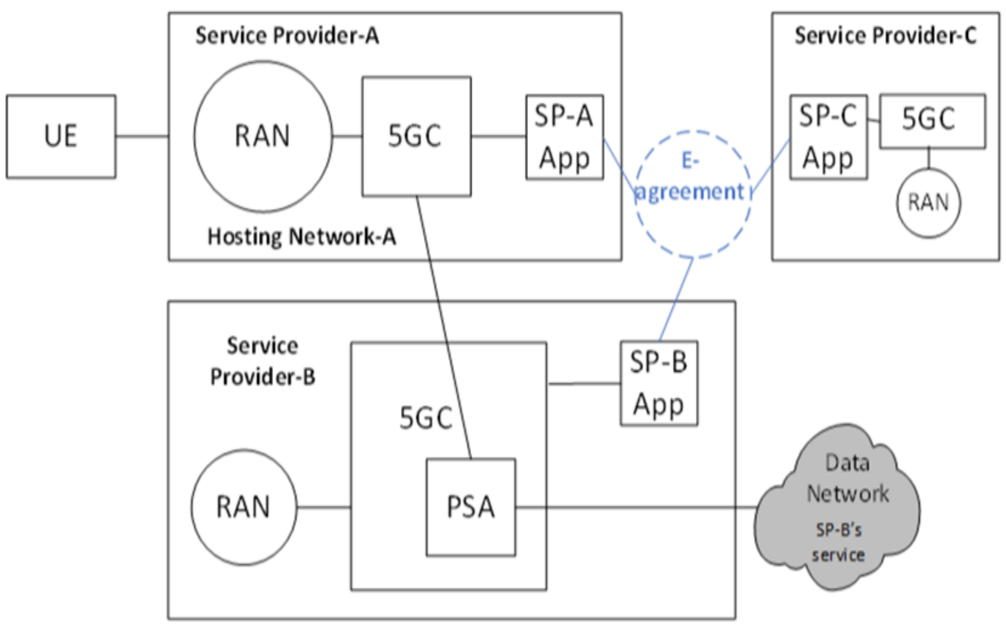
SP-C have no SLAs in place for the Services provided by SP-A's Hosting Network - A.

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.



Network Operators (MNOs) Relationship using Application Layer Approach

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), this key issue will study Solution on:

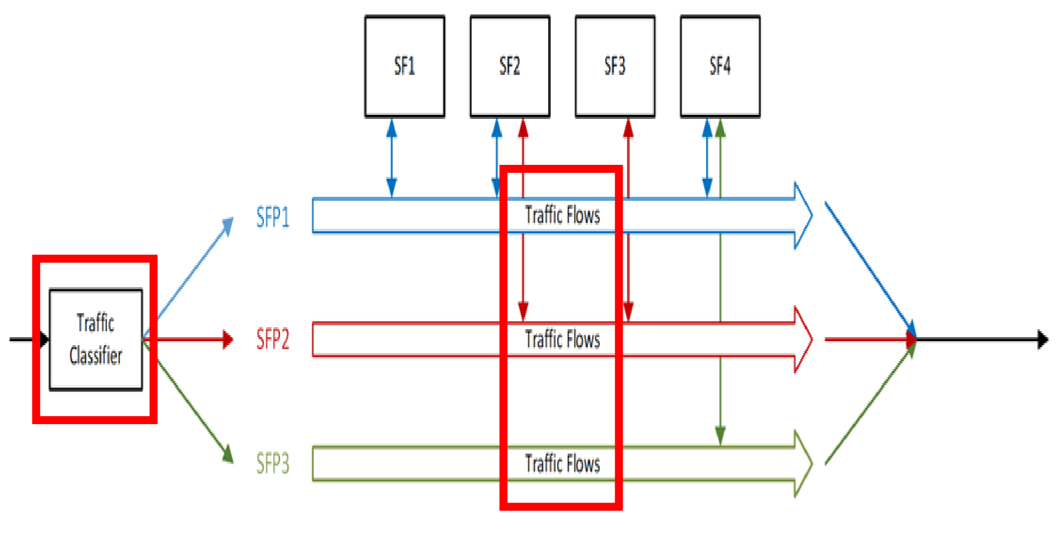
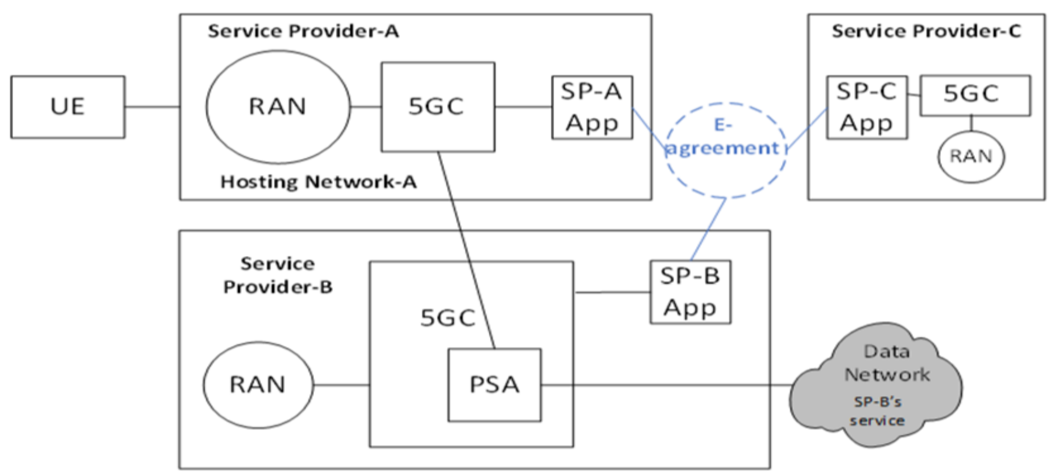


Figure 4-1: Illustration of the service function chaining concepts



Network Operators (MNOs) Relationship using Application Layer Approach

PALS Interworking between Networks Operators and Application Providers for Localized Services

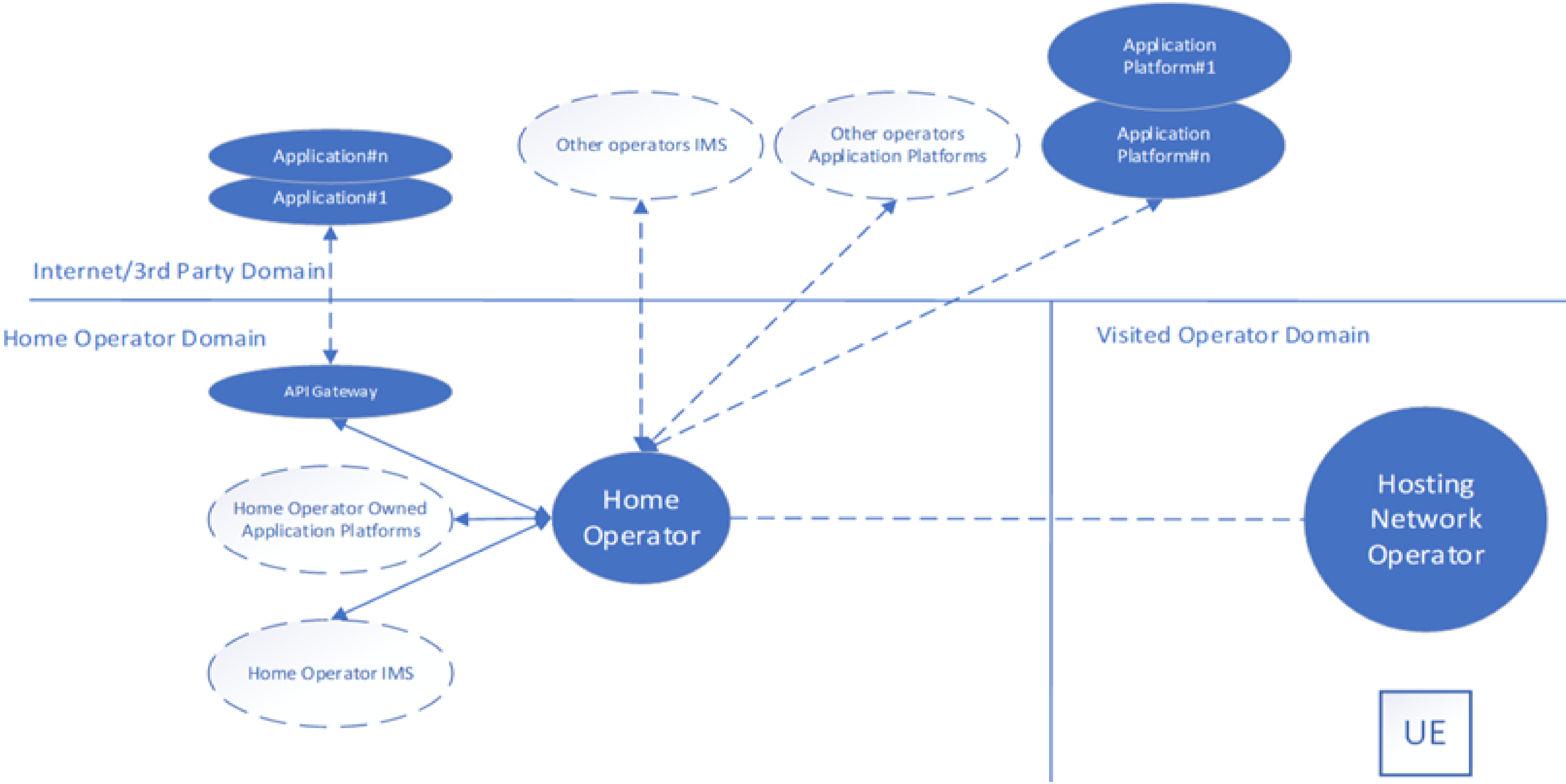


Fig.: Home Operator owned/collaborative Roaming Scenario - Home Routed

PALS Interworking between Networks Operators and Application Providers for Localized Services

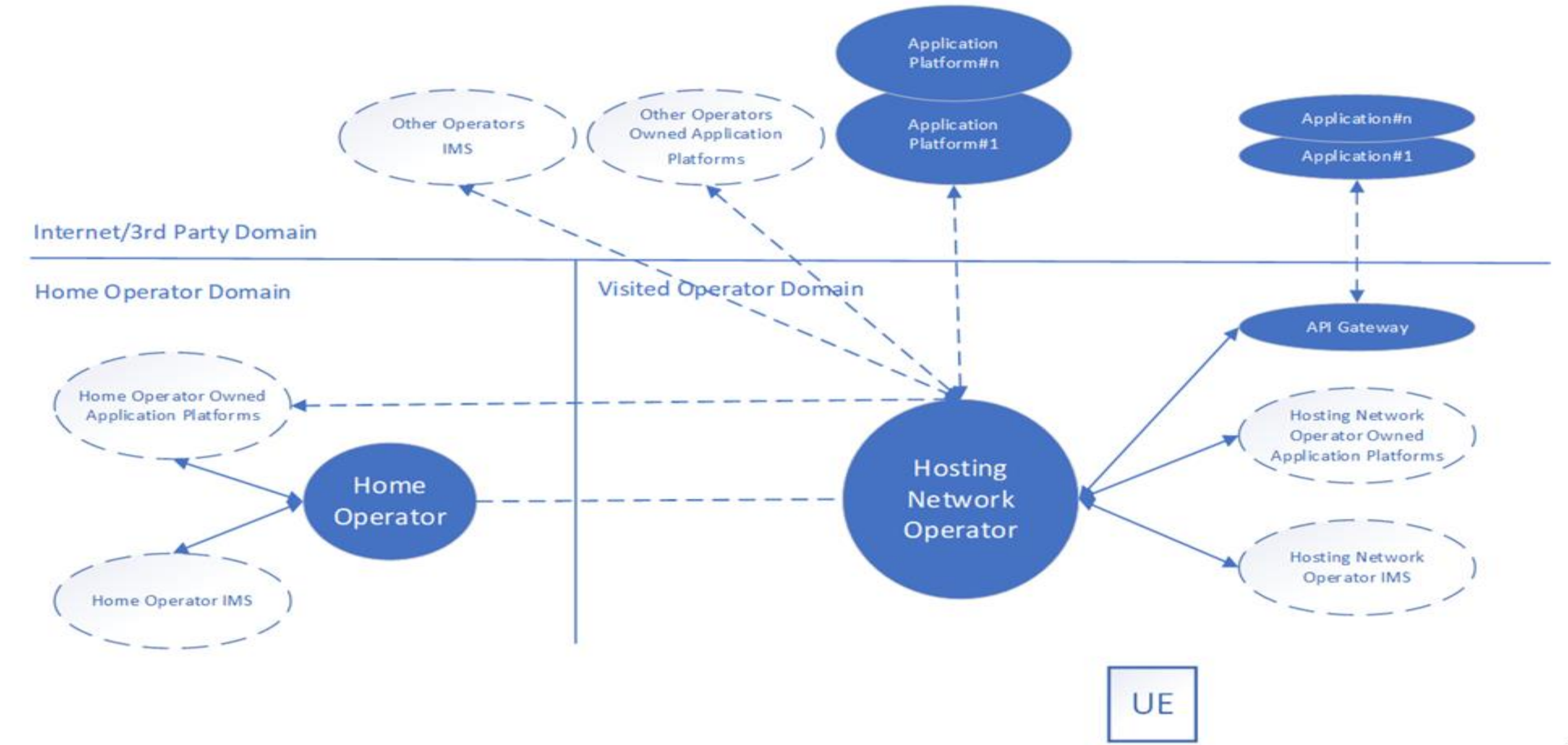


Fig.: Hosting Network Operator owned/collaborative Roaming Scenario - Local Breakout

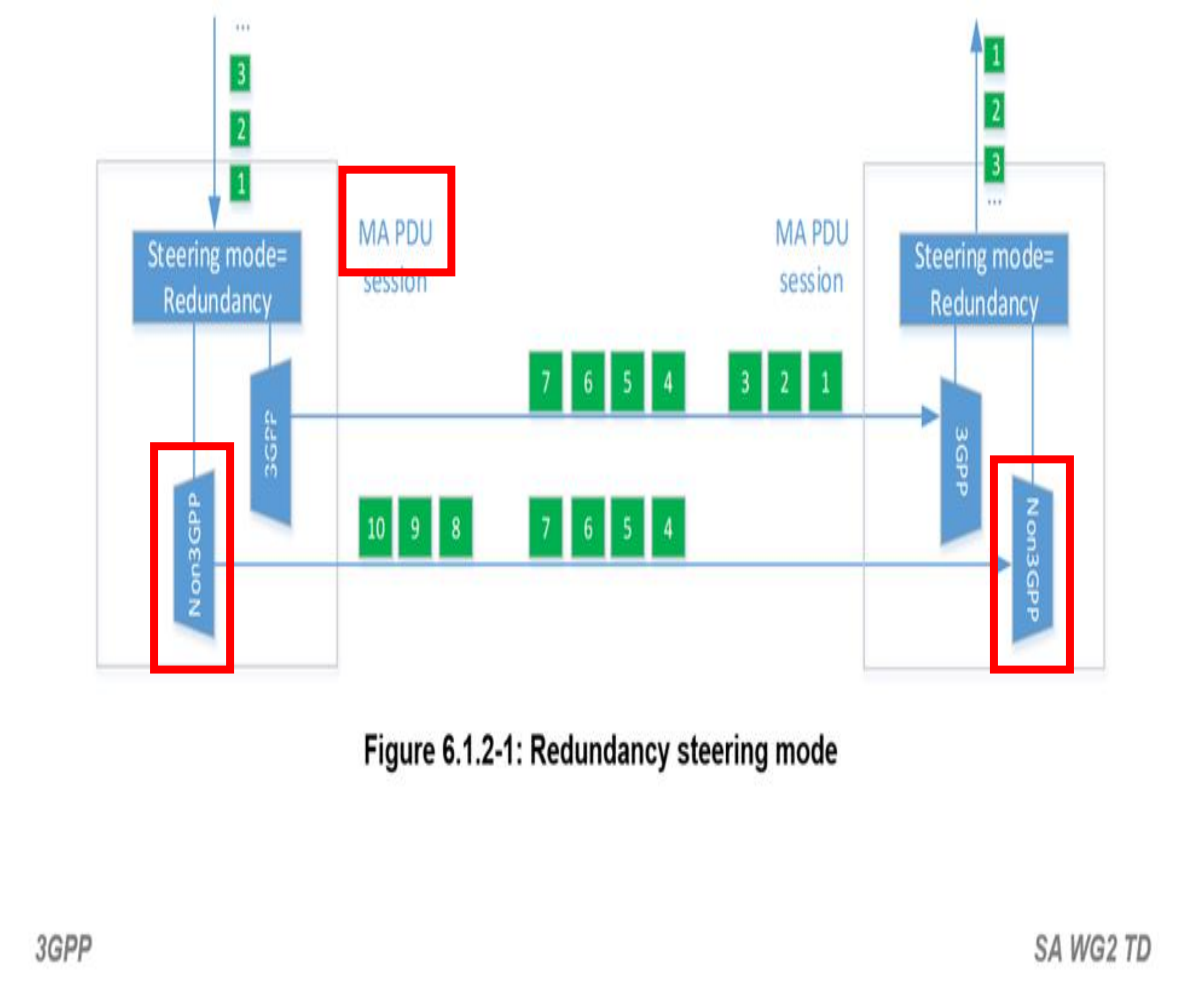


Figure 6.1.2-1: Redundancy steering mode

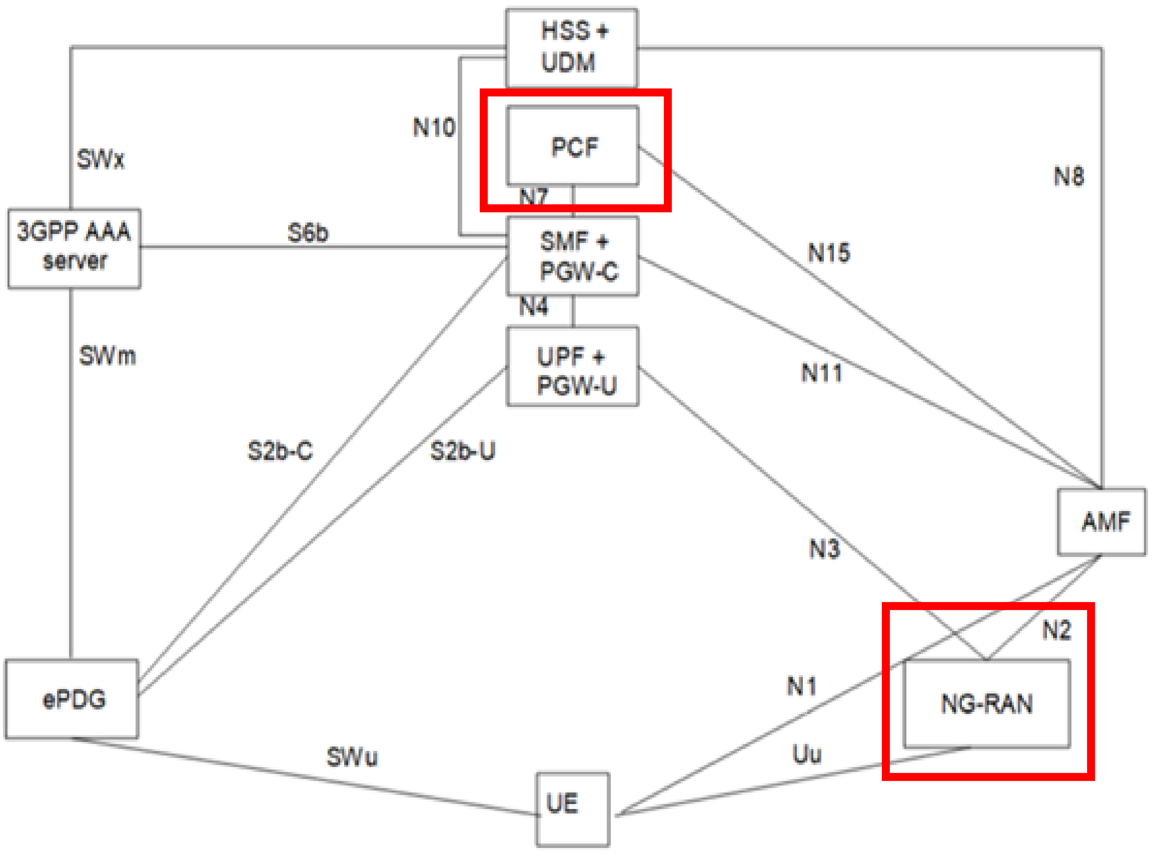


Figure 6.2.2-1: Multi-access between EPC and 5GC

General performance requirements - Video, Immage & Audio Production Applic.

Table: Performance Requirements for Airborne Base Stations for NPN

Profile	# of active UEs	UE Speed	Service Area	E2E latency	Packet error rate (Note 1)	Data rate UL	Data rate DL
NPN ground to air UHD up Link	10	500 km/h	700 km2 x 6000 m (Note 2)	40 ms	10^{-8} UL 10^{-7} DL	100 Mbit/s	20 Mbit/s
NPN ground to air HD up link	10	500 km/h	700 km2 x 6000 m (Note 2)	40 ms	10^{-8} UL 10^{-7} DL	80 Mbit/s	20 Mbit/s
NPN air to ground UHD down Link	2	500 km/h	700 km2 x 6000 m (Note 2)	40 ms	10^{-7} UL 10^{-8} DL	20 Mbit/s	100 Mbit/s
NPN air to ground HD down link	2	500 km/h	700 km2 x 6000 m (Note 2)	40 ms	10^{-7} UL 10^{-8} DL	20 Mbit/s	80 Mbit/s
NPN radio Camera UHD	10	200 km/h	1 km^2	3 ms	10^{-8} UL 10^{-7} DL	100 Mbit/s	20 Mbit/s
NPN radio camera HD	10	200 km/h	1 km^2	3 ms	10^{-8} UL 10^{-7} DL	80 Mbit/s	20 Mbit/s

NOTE 1: Packets that do not conform with the end-to-end latency are also accounted as error. The packet error rate requirement is calculated considering 1500 B packets, and 1 packet error per hour is $10^{-5}/(3^*x)$, where x is the data rate in Mbps.

NOTE 2: 6000 m = height but in a cone formation (i.e. ground coverage with a circle of diameter 30 KM)

Table: Performance Requirements of low-latency Periodic Deterministic Audio Transport Service in Presentation Use Cases

Profile	# of active UEs	UE Speed	Service Area	E2E latency (Note 1)	Transfer interval (Note 1)	Packet error rate (Note 2, Note 3)	Data rate UL	Data rate DL
Ad hoc	20	5 km/h	300 m x 300 m	4 ms	1 ms	10^{-5}	200 kbit/s	-
	8	stationary	300 m x 300 m	4 ms	1 ms	10^{-5}	-	200 kbit/s
Campus	1000	5 km/h	2 km x 2 km	4 ms	1 ms	10^{-5}	200 kbit/s	-
Conference	10	5 km/h	100 m x 100 m	4 ms	1 ms	10^{-5}	1.5 Mbit/s	-
	4	stationary	100 m x 100 m	4 ms	1 ms	10^{-5}	-	1.5 Mbit/s
Lecture room	4	5 km/h	10 m x 10 m	4 ms	1 ms	10^{-5}	50 kbit/s	-
	2	stationary	10 m x 10 m	4 ms	1 ms	10^{-5}	-	50 kbit/s

NOTE 1: Transfer interval refers to periodicity of the packet transfers. It has to be constant during the whole operation. The value given in the table is a typical one, however other transfer intervals are possible as long as the end-to-end latency is ≤ (5 ms – Transfer interval).
NOTE 2: Packet error rate is related to a packet size of (Transfer interval × data rate). Packets that do not conform with the end-to-end latency are also accounted as error.
NOTE 3: The given requirement for a packet error rate assumes a uniform error distribution. The requirement for packet error rate is stricter if packet errors occur in bursts.

Table: Performance Requirements of Professional Low-latency Periodic Deterministic Audio Transport Service

Profile	# of active UEs	UE Speed	Service Area	E2E latency (Note 1)	Transfer interval (Note 1)	Packet error rate (Note 2, Note 3)	Data rate UL	Data rate DL
Music Festival	200	10 km/h	500 m x 500 m	750 µs	250 µs	10^{-6}	500 kbit/s	-
	100	10 km/h	500 m x 500 m	750 µs	250 µs	10^{-6}	-	1 Mbit/s
Musical	30	50 km/h	50 m x 50 m	750 µs	250 µs	10^{-6}	500 kbit/s	-
	20	50 km/h	50 m x 50 m	750 µs	250 µs	10^{-6}	-	1 Mbit/s
	10	-	50 m x 50 m	750 µs	250 µs	10^{-6}	-	500 kbit/s
Semi-professional	10	5 km/h	5 m x 5 m	750 µs	250 µs	10^{-6}	100 kbit/s	-
	10	5 km/h	5 m x 5 m	750 µs	250 µs	10^{-6}	-	200 kbit/s
	2	-	5 m x 5 m	750 µs	250 µs	10^{-6}	-	100 kbit/s
AV production	20	5 km/h	30 m x 30 m	750 µs	250 µs	10^{-6}	1.5 Mbit/s	-
	10	5 km/h	30 m x 30 m	750 µs	250 µs	10^{-6}	-	3 Mbit/s
Audio Studio	30	-	10 m x 10 m	750 µs	250 µs	10^{-6}	5 Mbit/s	-
	10	5 km/h	10 m x 10 m	750 µs	250 µs	10^{-6}	-	1 Mbit/s

NOTE 1: Transfer interval refers to periodicity of the packet transfers. It has to be constant during the whole operation. The value given in the table is a typical one, however other transfer intervals are possible as long as the end-to-end latency is ≤ (1ms – Transfer interval).
NOTE 2: Packet error rate is related to a packet size of (transfer interval × data rate). Packets that do not conform with the end-to-end latency are also accounted as error.
NOTE 3: The given requirement for a packet error rate assumes a uniform error distribution. The requirement for packet error rate is stricter if packet errors occur in bursts.

Performance requirements - High Data Rates and Traffic Densities

High Data Rate and Low Latency - AR/VR

Table: Performance Requirements for High Data Rate and Traffic Density Scenarios

	Scenario	Experienced data rate (DL)	Experienced data rate (UL)	Area traffic capacity (DL)	Area traffic capacity (UL)	Overall user density	Activity factor	UE speed	Coverage
1	Urban macro	50 Mbit/s	25 Mbit/s	100 Gbit/s/km^2 (note 4)	50 Gbit/s/km^2 (note 4)	10 000/km^2	20 %	Pedestrians and users in vehicles (up to 120 km/h	Full network (note 1)
2	Rural macro	50 Mbit/s	25 Mbit/s	1 Gbit/s/km^2 (note 4)	500 Mbit/s/km^2 (note 4)	100/km^2	20 %	Pedestrians and users in vehicles (up to 120 km/h	Full network (note 1)
3	Indoor hotspot	1 Gbit/s	500 Mbit/s	15 Tbit/s/km^2	2 Tbit/s/km^2	250 000/km^2	note 2	Pedestrians	Office and residential (note 2) (note 3)
4	Broadband access in a crowd	25 Mbit/s	50 Mbit/s	[3,75] Tbit/s/km^2	[7,5] Tbit/s/km^2	[500 000]/km^2	30 %	Pedestrians	Confined area
5	Dense urban	300 Mbit/s	50 Mbit/s	750 Gbit/s/km^2 (note 4)	125 Gbit/s/km^2 (note 4)	25 000/km^2	10 %	Pedestrians and users in vehicles (up to 60 km/h)	Downtown (note 1)
6	Broadcast-like services	Maximum 200 Mbit/s (per TV channel)	N/A or modest (e.g. 500 kbit/s per user)	N/A	N/A	[15] TV channels of [20 Mbit/s] on one carrier	N/A	Stationary users, pedestrians and users in vehicles (up to 500 km/h)	Full network (note 1)
7	High-speed train	50 Mbit/s	25 Mbit/s	15 Gbit/s/train	7,5 Gbit/s/train	1 000/train	30 %	Users in trains (up to 500 km/h)	Along railways (note 1)
8	High-speed vehicle	50 Mbit/s	25 Mbit/s	[100] Gbit/s/km^2	[50] Gbit/s/km^2	4 000/km^2	50 %	Users in vehicles (up to 250 km/h)	Along roads (note 1)
9	Airplanes connectivity	15 Mbit/s	7,5 Mbit/s	1,2 Gbit/s/plane	600 Mbit/s/plane	400/plane	20 %	Users in airplanes (up to 1 000 km/h)	(note 1)

NOTE 1: For users in vehicles, the UE can be connected to the network directly, or via an on-board moving base station.
NOTE 2: A certain traffic mix is assumed; only some users use services that require the highest data rates [2].
NOTE 3: For interactive audio and video services, for example, virtual meetings, the required two-way end-to-end latency (UL and DL) is 2-4 ms while the corresponding experienced data rate needs to be up to 8K 3D video [300 Mbit/s] in uplink and downlink.
NOTE 4: These values are derived based on overall user density. Detailed information can be found in [10].
NOTE 5: All the values in this table are targeted values and not strict requirements.

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.

Timing Resilience Accuracy KPIs

Table: Timing Resilience Accuracy KPIs for Members of Participants of a Trading Venue

Type of trading activity	Maximum divergence from UTC	Granularity of the timestamp (note 1)
Activity using high frequency algorithmic trading technique	100 µs	≤1 µs
Activity on voice trading systems	1 s	≤1 s
Activity on request for quote systems where the response requires human intervention or where the system does not allow algorithmic trading	1 s	≤1 s
Activity of concluding negotiated transactions	1 s	≤1 s
Any other trading activity	1 ms	≤1 ms
NOTE 1: Only relevant for the case where the time synchronization assists in configuring the required granularity for the timestamp (for direct use), otherwise it will be configured separately as part of the financial transaction timestamp process.		

Table: Key Performance for UE to Network Relaying

Scenario	Max. data rate (DL)	Max. data rate (UL)	End-to-end latency (note 7)	Area traffic capacity (DL)	Area traffic capacity (UL)	Area user density	Area	Range of a single hop (note 8)	Estimated number of hops
InHome Scenario (note 1)	1 Gbit/s	500 Mbit/s	10 ms	5 Gbit/s/ home	2 Gbit/s /home	50 devices /house	10 m x 10m – 3 floors	10 m indoor	2 to 3
Factory Sensors (note 2)	100 kbit/s	5 Mbit/s	50 ms to 1 s	1 Gbit/s /factory	50 Gbit/s /factory	10000 devices /factory	100 m x 100 m	30 m indoor / metallic	2 to 3
Smart Metering (note 3)	100 bytes / 15 mins	100 bytes / 15 mins	10 s	200 x 100 bytes / 15 mins /hectare	200 x 100 bytes / 15 mins /hectare	200 devices /hectare	100 m x 100 m	> 100 m indoor / deep indoor	2 to 5
Containers (note 4)	100 bytes / 15 mins	100 bytes / 15 mins	10 s	15000 x 100 bytes / 15 mins /ship	15000 x 100 bytes / 15 mins /ship	15000 containers /ship	400 m x 60 m x 40 m	> 100 m indoor / outdoor / metallic	3 to 9
Freight Wagons	100 bytes / 15 mins	100 bytes / 15 mins	10 s	200 x 100 bytes / 15 mins /train	200 x 100 bytes / 15 mins /train	120 wagons /train	1 km	> 100 m outdoor / tunnel	10 to 15
Public Safety (note 5)	12 Mbit/s	12 Mbit/s	30 ms	20 Mbit/s /building	40 Mbit/s /building	30 devices /building	100 m x 100 m – 3 floors	> 50 m indoor (floor or stairwell)	2 to 4
Wearables (note 6)	10 Mbit/s	10 Mbit/s	10 ms	20 Mbit/s per 100 m²	20 Mbit/s per 100 m²	10 wearables per 100 m²	10 m x 10 m	10 m indoor / outdoor	1 to 2

NOTE 1: Area traffic capacity is determined by high bandwidth consuming devices (e.g. ultra HD TVs, VR headsets), the number of devices has been calculated assuming a family of 4 members.
NOTE 2: Highest data rate assumes audio sensors with sampling rate of 192 kHz and 24 bits sample size.
NOTE 3: Three meters (gas, water, electricity) per house, medium density of 50 to 70 houses per hectare.
NOTE 4: A large containership with a mix of 20 foot and 40 foot containers is assumed.
NOTE 5: A mix of MCPTT, MCVideo, and MCData is assumed. Average 3 devices per firefighter / police officer, of which one video device. Area traffic based on 1080 p, 60 fps is 12 Mbit/s video, with an activity factor of 30% in uplink (30% of devices transmit simultaneously at high bitrate) and 15% in downlink.
NOTE 6: Communication for wearables is relayed via a UE. This relay UE may use a further relay UE.
NOTE 7: End-to-end latency implies that all hops are included.
NOTE 8: 'Metallic' implies an environment with a lot of metal obstructions (e.g. machinery, containers). 'Deep indoor' implies that there may be concrete walls / floors between the devices.
NOTE 9: All the values in this table are example values and not strict requirements.

KPIs for AI/ML Model Transfer in 5GS

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 may take place in order to satisfy the reliability requirement.

Table: KPI Table of split AI/ML Inference between UE and Network Server/AF

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
2ms	1.08Gbit/s	0.27 MByte	99.999 %	99.9%				99.999%	Split AI/ML image recognition
100ms	1.5Mbit/s				100ms	150 Mbit/s	1.5 MByte /frame		Enhanced media recognition
		4.7Mbit/s			12ms	320Mbit/s	40kByte		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 may take place in order to satisfy the reliability requirement.

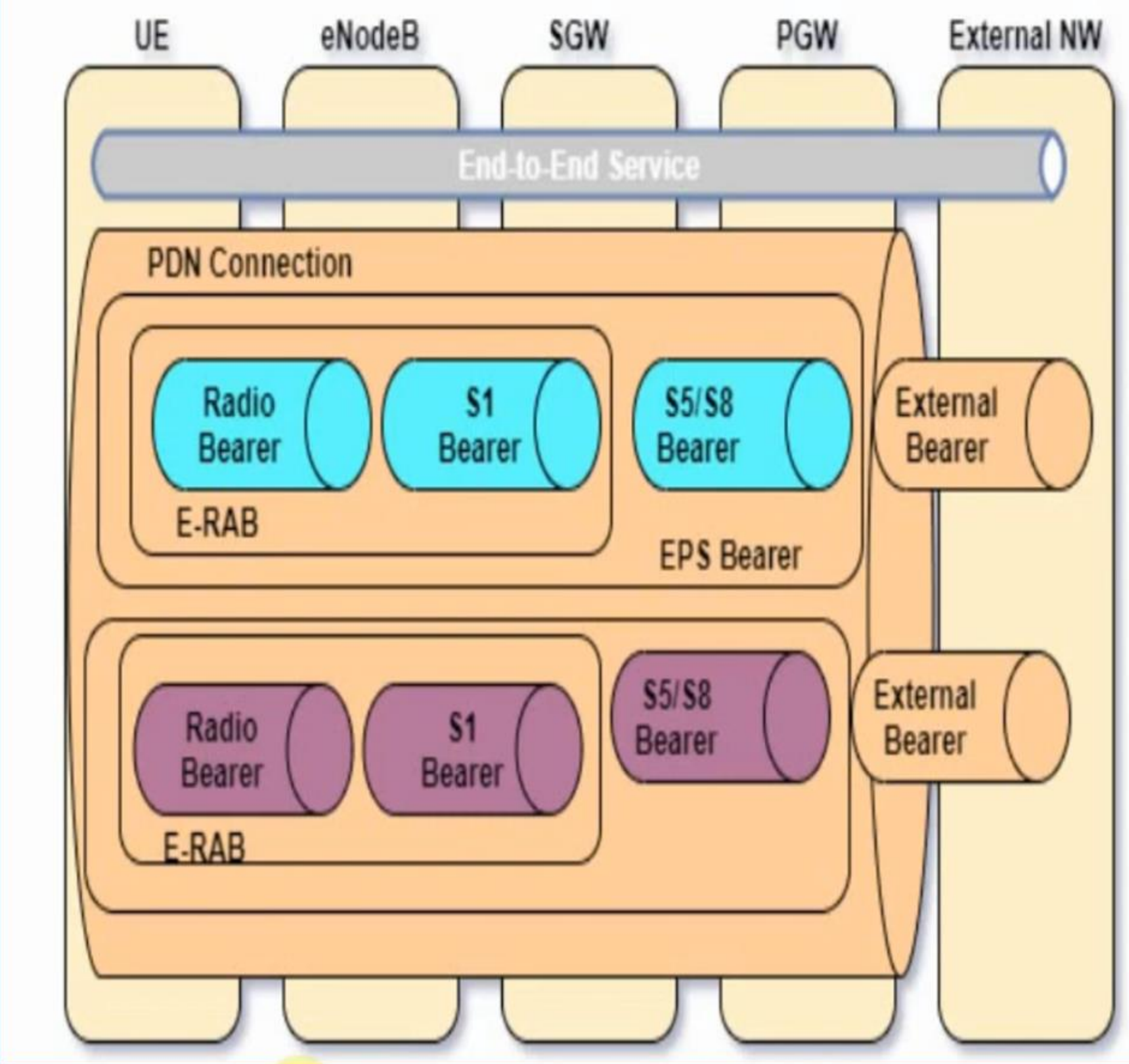
Table: KPI Table of Federated Learning between UE and Network Server/AF

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

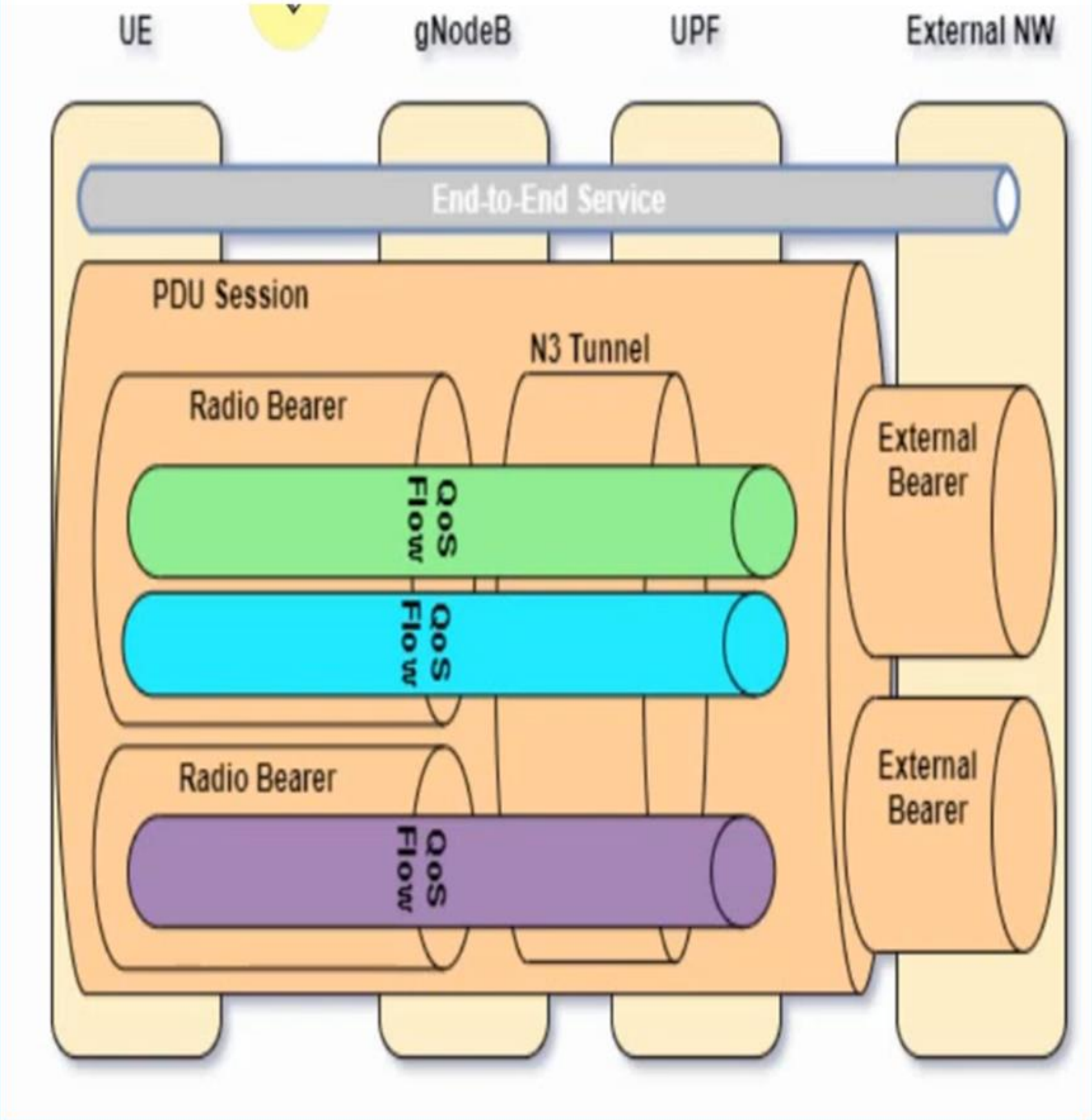
Ref.: 3GPP, Rel. 17

5G QoS 4G vs 5G QoS

4G/LTE/EPC QoS - QCI (QoS Class Identifier)



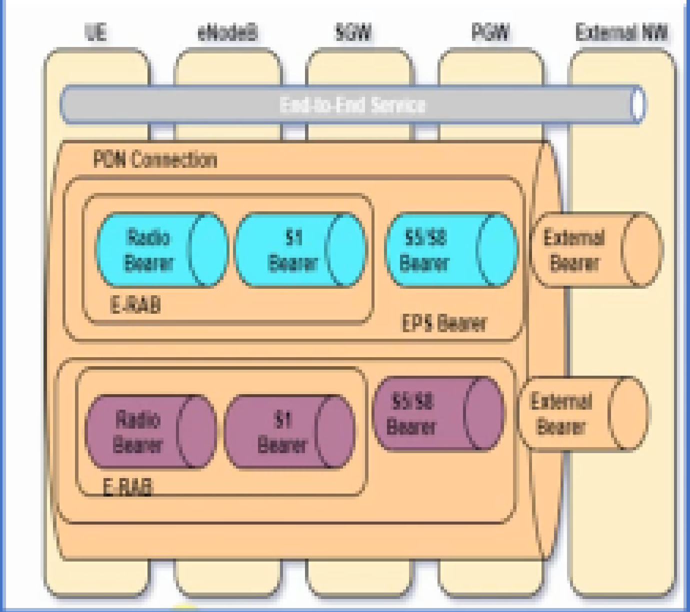
5G QoS - 5QI



Ref. Telco Bytes Dec 2020

5G QoS 4G vs 5G QoS

4G/LTE QoS QCI



QoS Class Identifier (QCI): A scalar that is used as a reference to a specific packet forwarding behaviour (e.g. packet loss rate, packet delay budget) to be provided to a SDF. This may be implemented in the access network by the QCI referencing node specific parameters that control packet forwarding treatment (e.g. scheduling weights, admission thresholds, queue management thresholds, link layer protocol configuration, etc.), that have been pre-configured by the operator at a specific node(s) (e.g. eNodeB).

- AS-level mapping rules in the UE and in the NG-RAN associate UL and DL QoS Flows with DRBs.

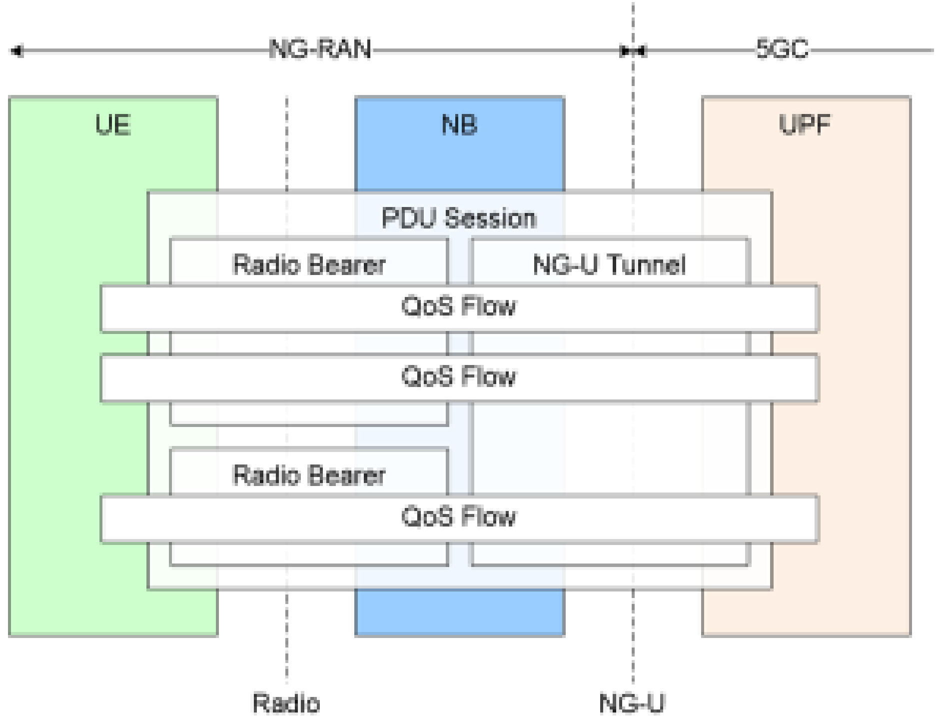


Figure 12-1: QoS architecture

NG-RAN and 5GC ensure quality of service (e.g. reliability and target delay) by mapping packets to appropriate QoS Flows and DRBs. Hence there is a 2-step mapping of IP-flows to QoS flows (NAS) and from QoS flows to DRBs (Access Stratum).

3GPP

AS - Access Stratum
DRB - Data Radio Bearers

Ref.: 3GPP, Rel. 17

The 5G QoS Model is based on QoS Flows.

The 5G QoS Model also supports Reflective QoS

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

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

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

QFI shall be used for all PDU Session Types and unique within a PDU Session.

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

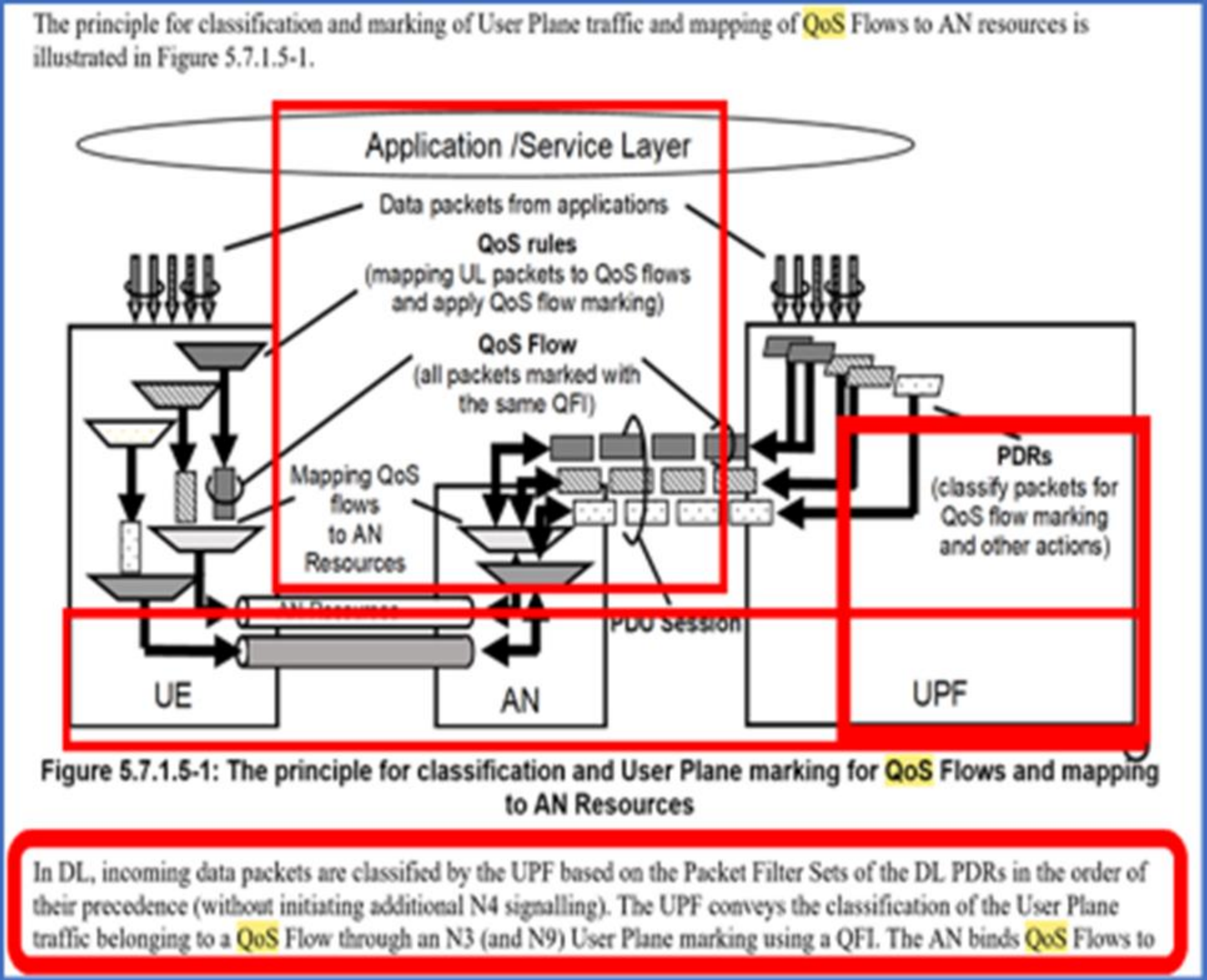

The principle for classification and marking of User Plane traffic and mapping of QoS Flows to AN resources is illustrated in Figure 5.7.1.5-1.

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

5QI - 5G QoS Identifier

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 UPF 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 - 4G LTE QoS Class Identifier

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)	GBR	4	150 ms (NOTE 1, NOTE 11)	10^{-3}	Conversational Video (Live Streaming)
3 (NOTE 3, NOTE 14)	GBR	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)	GBR	5	300 ms (NOTE 1, NOTE 11)	10^{-6}	Non-Conversational Video (Buffered Streaming)
65 (NOTE 3, NOTE 9, NOTE 12)	GBR	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)	GBR	2	100 ms (NOTE 1, NOTE 10)	10^{-2}	Non-Mission-Critical user plane Push To Talk voice
67 (NOTE 3, NOTE 12)	GBR	1.5	100 ms (NOTE 1, NOTE 10)	10^{-3}	Mission Critical Video user plane
75 (NOTE 14)	GBR	2.5	50 ms (NOTE 1)	10^{-2}	V2X messages
71	GBR	5.6	150ms (NOTE 1, NOTE 16)	10^{-6}	"Live" Uplink Streaming (e.g. TS 26.238 [53])
72	GBR	5.6	300ms (NOTE 1, NOTE 16)	10^{-4}	"Live" Uplink Streaming (e.g. TS 26.238 [53])
73	GBR	5.6	300ms (NOTE 1, NOTE 16)	10^{-8}	"Live" Uplink Streaming (e.g. TS 26.238 [53])
74	GBR	5.6	500ms (NOTE 1, NOTE 16)	10^{-8}	"Live" Uplink Streaming (e.g. TS 26.238 [53])
76	GBR	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)	Non-GBR	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)	Non-GBR	7	100 ms (NOTE 1, NOTE 10)	10^{-3}	Voice, Video (Live Streaming) Interactive Gaming
8 (NOTE 5)	Non-GBR	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)	Non-GBR	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)	GBR	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)	GBR	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)	GBR	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.

Ref.: 3GPP, Rel. 17

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

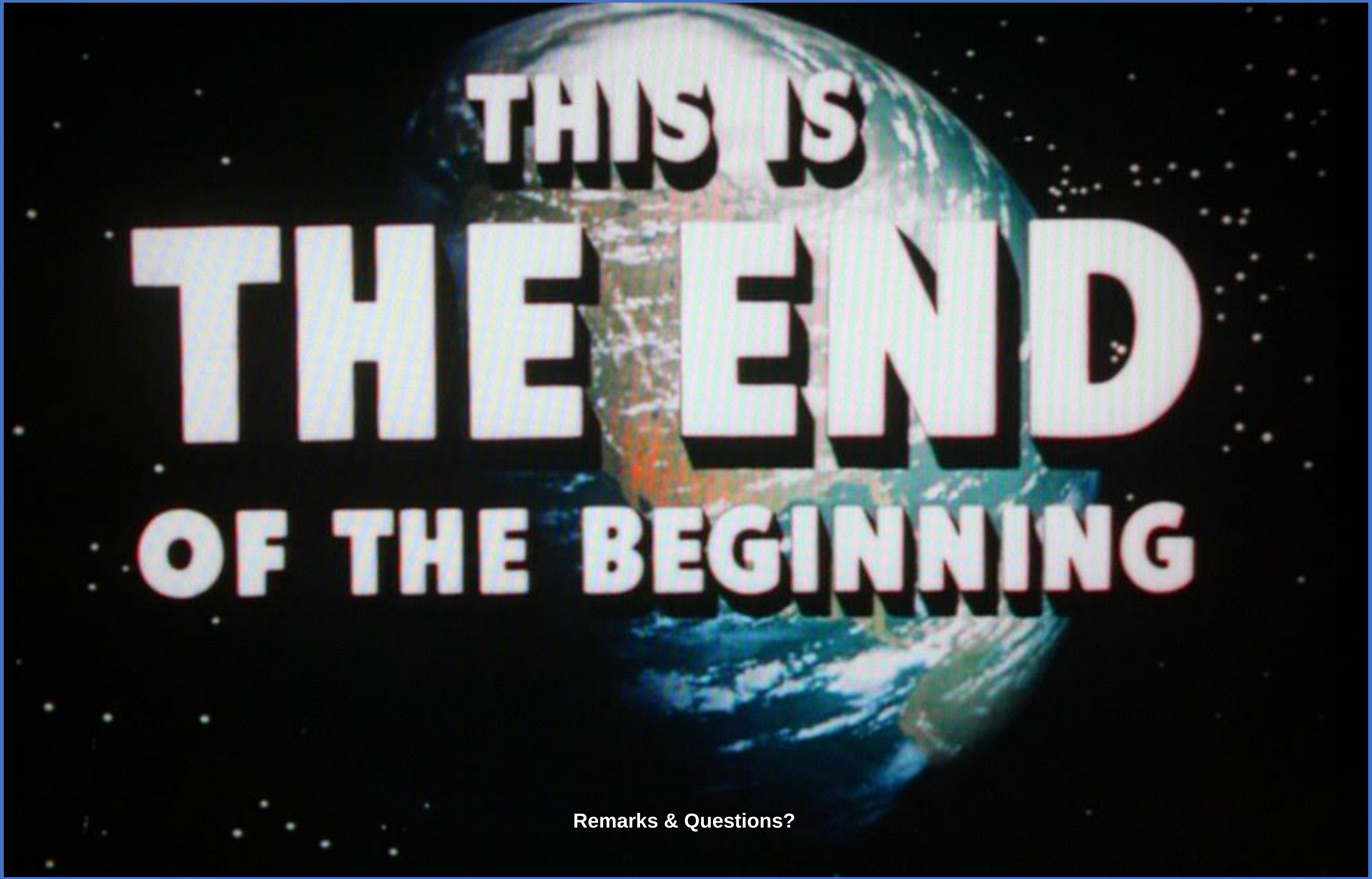
Table 71 List of attributes needed for NEST for MIoT SST

Ref.: 3GPP, Rel. 17

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			

Ref.: 3GPP, Rel. 17



Remarks & Questions?