5G System Architecture Capability enhancements on

Wireless and Wireline Convergence Access support

for

5G Services

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2023 - 08- 24 Rev PA03

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0. "5G Release History" - Adding in Rel-16 5G NR Capability for Full Wired Ethernet Replacement in Factories - 1

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

0. "5G Release History" - Adding in Rel-16 5G NR Capability for Full Wired Ethernet Replacement in Factories - 2

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

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Table: 5G Service Performance Requirements for Wired to Wireless Link Replacement

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

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

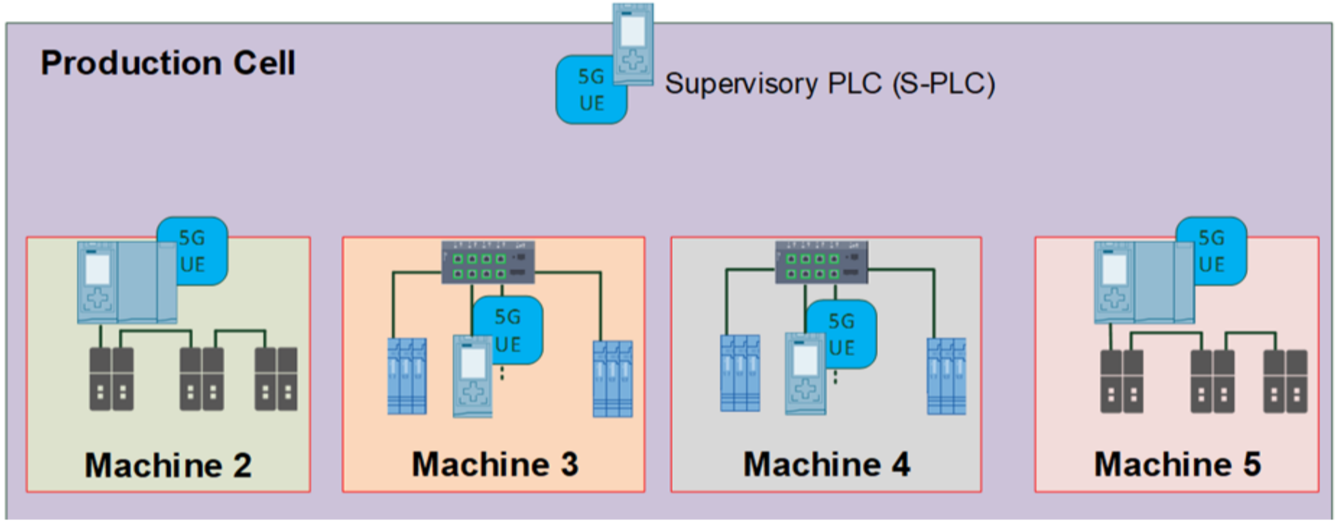

Figure: 5G Wired to Wireless Link Replacement example of Four Cooperating Machines with Wireless Connection

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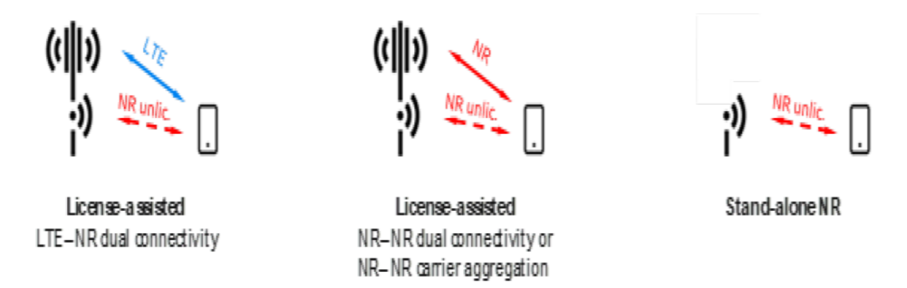

Fig. 3.10. License-assisted (left and middle) and stand-alone (right) operation of NR in unlicensed spectra.

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

This Scenario targets NPN

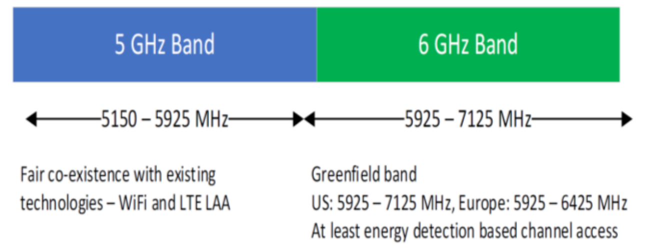

Fig. 3.9. Spectrum priorities for NR-U.

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

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

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

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

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

Thus, initial Access & Mobility are handled entirely using un-licensed spectra.

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

Ref. 5GA, 3GPP Rel. 16 & 17, & B., Jan 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:

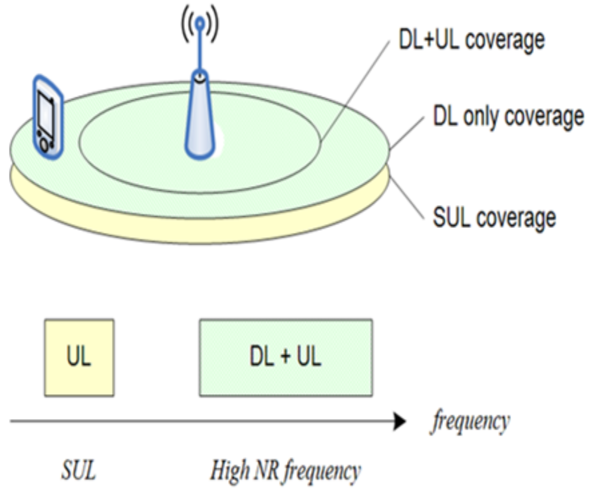

Figure B.1-1: Example of Supplementary Uplink

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.

1. 5G System Architecture enhancements on Wireless and Wireline Convergence Access support

This following slides present some of the enhancements to 5GS Architecture and related to it Procedure(s) and Flow(s), Policy and Charging Control for the 5G System as defined by 3GPP in the respective specifications in order to support Wireline Access Network and Fixed Wireless Access.

Network selection

The HPLMN is implicitly selected by Wired Physical Connectivity between 5G-RG (5G Residential Gateway) or FN-RG (Fixed Network RG) and W-AGF (Wireline-Access Gateway Function).

NOTE 1: *The 5G-RG or FN-RG can only connect to a Single Physical Wired Access W-5GAN to a W-AGF configured at line provisioning by the Operator, in addition no PLMN information is advertised by AS Protocols in W-5GAN, since the Network selection feature is not supported.*

In the case of 5G-RG connected via FWA the 5GS Architecture specification applies with the following difference:

- The PLMN selection defined in 5GS Architecture applies with the UE replaced by 5G-RG.

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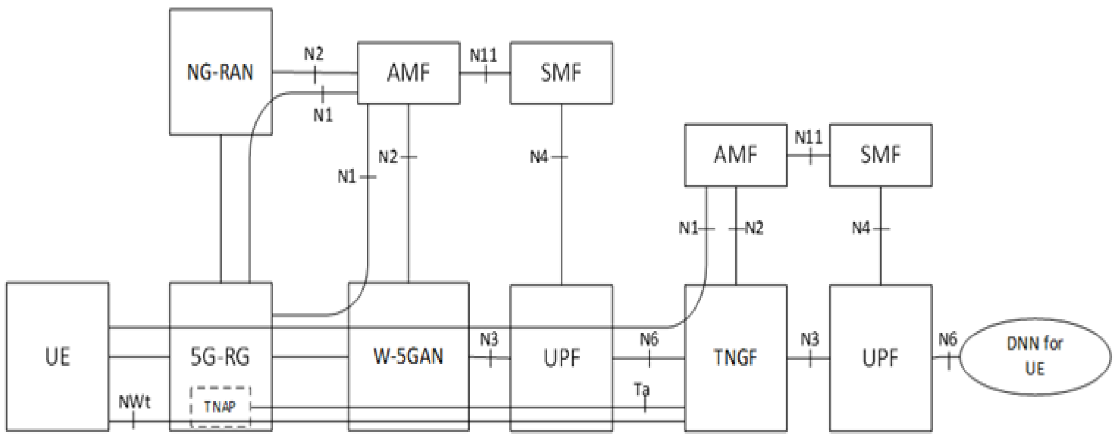

Figure: 5G System Non-Roaming Architecture for UE behind 5G-RG using Trusted N3GPP Access

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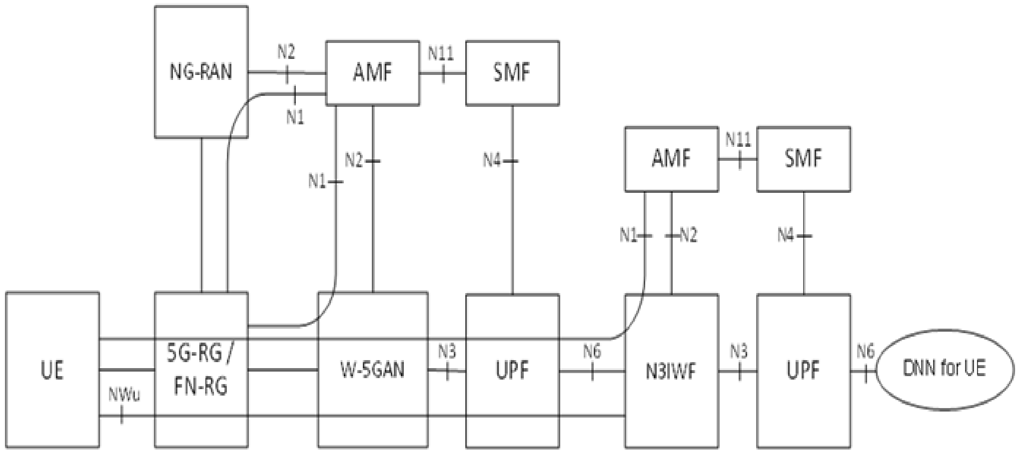

Figure: 5G System Architecture for UE behind 5G-RG and FN-RG using Untrusted N3GPP Access

1. 5G System Architecture enhancements on Wireless and Wireline Convergence Access support

Identification and Authentication

In the case of **5G-RG** *connected via* **W-5GAN or FWA**, the 5GS Architecture specification applies with the following difference:

- **UE** is replaced by **5G-RG.**

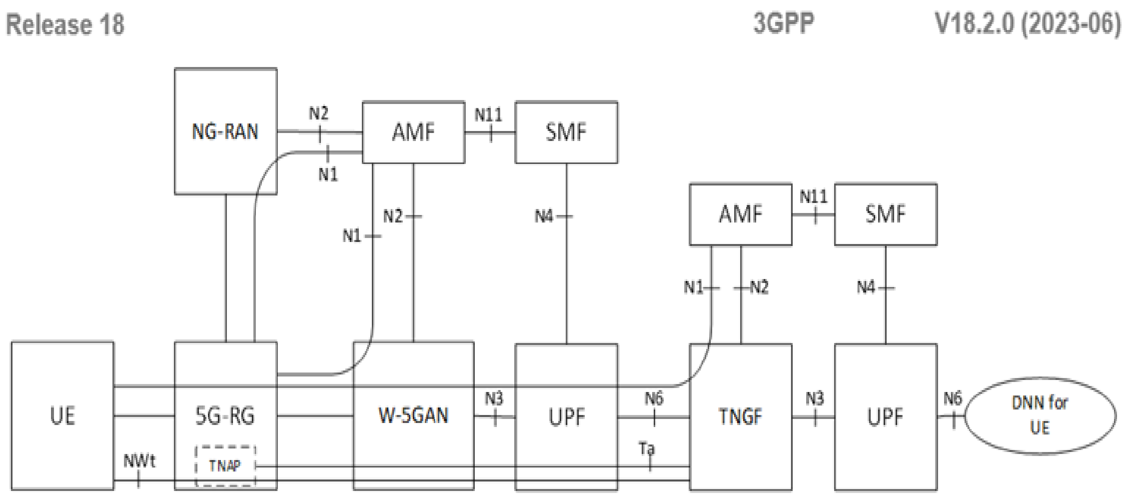

Figure: 5G System Non-Roaming Architecture for UE behind 5G-RG using Trusted N3GPP Access

In the case of **FN-RG** connected via **W-5GAN**, the 5GS Architecture specification applies with the following differences:

- UE is replaced by FN-RG.
- The W-AGF provides the NAS signalling connection to the 5GC on behalf of the FN-RG.
- The W-5GAN may authenticate the FN-BRG per BBF specifications. The W-5GAN may authenticate the FN-CRG per CableLabs DOCSIS MULPI.

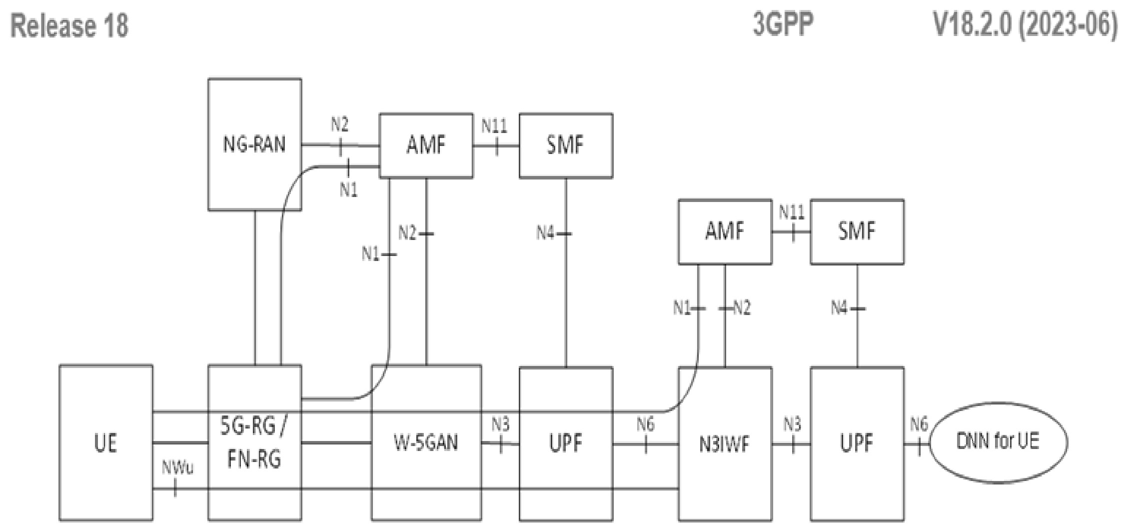

Figure: 5G System Architecture for UE behind 5G-RG and FN-RG using Untrusted N3GPP Access

Authorisation

In the case of **5G-RG** connected via **W-5GAN or FWA**, the 5GS Architecture specification applies with the following differences:

- UE is replaced by 5G-RG.

In the case of **FN-RG** connected via **W-5GAN**, the 5GS Architecture specification applies with the following differences:

- **UE** is replaced by **FN-RG**.
- **W-AGF** performs the **UE** Registration procedure on behalf of the **FN-RG**.

Access Control and Barring

In the case of **5G-RG** or **FN-RG** connected via **W-5GAN** the Access Control and Barring defined in the 5GS Architecture is not applicable.

In the case of **5G-RG** connected via **FWA** the 5GS Architecture specification applies with the following difference:
- UE is replaced by 5G-RG.

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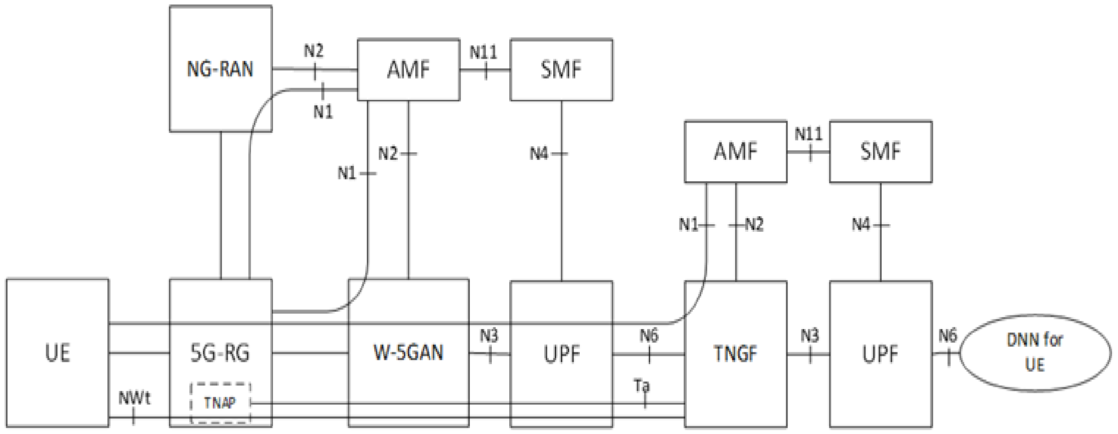

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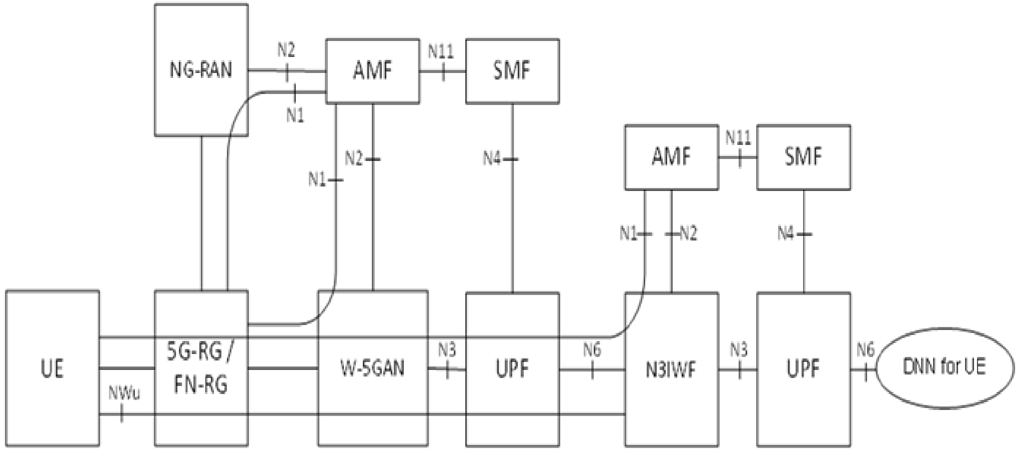

Figure: 5G System Architecture for UE behind 5G-RG and FN-RG using Untrusted N3GPP Access

Registration and Connection Management

Registration Management when **5G-RG or FN-RG** is connected to **5GC** via Wireline Access is described in the 5GS Architecture specification.

Registration Management when **5G-RG** is connected to **5GC** via **NG RAN A**ccess is described in the 5GS Architecture specification.

Connection Management when **5G-RG or FN-RG** is connected to **5GC** via Wireline Access is described in the 5GS Architecture specification.

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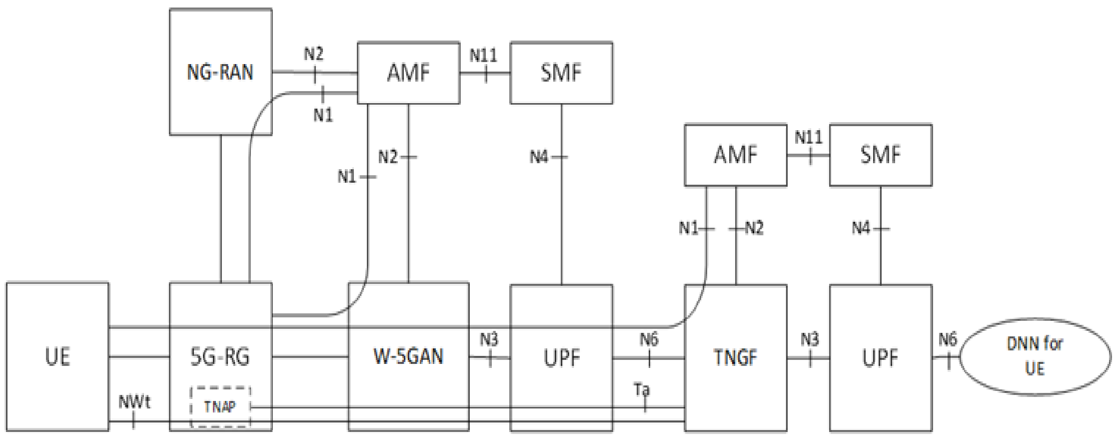

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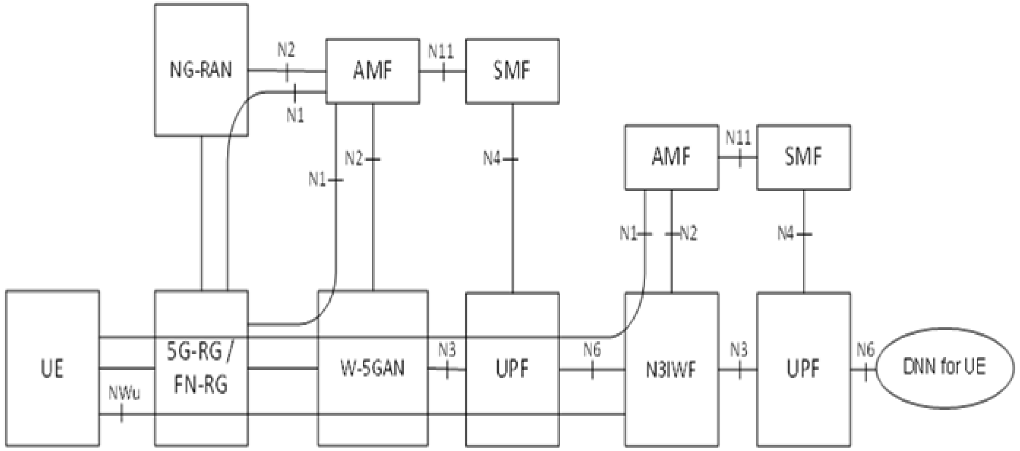

Figure: 5G System Architecture for UE behind 5G-RG and FN-RG using Untrusted N3GPP Access

Mobility Restrictions

Mobility Restrictions restrict Service Access of an 5G-RG depending on RG location.

For a **5G-RG connecting over NG-RAN**, the *Mobility Restriction* functionality as described in the 5GS Architecture applies.

For an **5G-RG** connecting over Wireline Access, the Mobility Restriction functionality is described in this clause.

Mobility Restrictions do not apply to scenarios with FN-BRG (Fixed Network Broadband RG).

NOTE 1: *Since Access to 5GC for FN-BRG Subscriptions are identified by a SUPI determined from the GLI as described. Such Subscriptions are by definition restricted to a specific location.*

NOTE 2: *For FN-CRG Subscriptions, HFC Node ID is used to identify the location of FN-CRG, thus Service Area restrictions for the FN-CRG can be identified by an HFC_Node ID, or by a list of HFC_Node ID.* Mobility Restrictions for Wireline Access consists of Forbidden Area & Service Area Restrictions, as described in the following clauses.

Management of Forbidden Area in Wireline Access

In a Forbidden Area, the 5G-RG, based on subscription, is not permitted by the 5GC to initiate any communication with the 5GC for this PLMN or SNPN.

The UDM stores the Forbidden Area for wireline access in the same way as for 3GPP access, with the following differences:
- For Subscriptions for 5G-BRG, GLI is used to describe the Forbidden Area.
- For subscriptions for 5G-CRG and FN-CRG, HFC Node IDs are used to describe the Forbidden Area (instead of TA).
- The Forbidden Area in UDM can be encoded as a "allow list" indicating the non-forbidden area. In this case all GLI or HFC_Node ID values not included in the list are considered forbidden.

NOTE: The use of "allow list" is to ensure an efficient Forbidden Area definition if only a small set of GLI / HFC Node ID values are not forbidden.

Forbidden Area is enforced by AMF, based on Subscription Data and the Location Information received from W-AGF.

The AMF rejects a Registration Request from a 5G-RG or the W-AGF acting on behalf of a FN-CRG in a Forbidden Area with a suitable cause code. The 5G-RG behaviour depends on the Network Response (cause code from AMF) that informs the RG that communication is forbidden.

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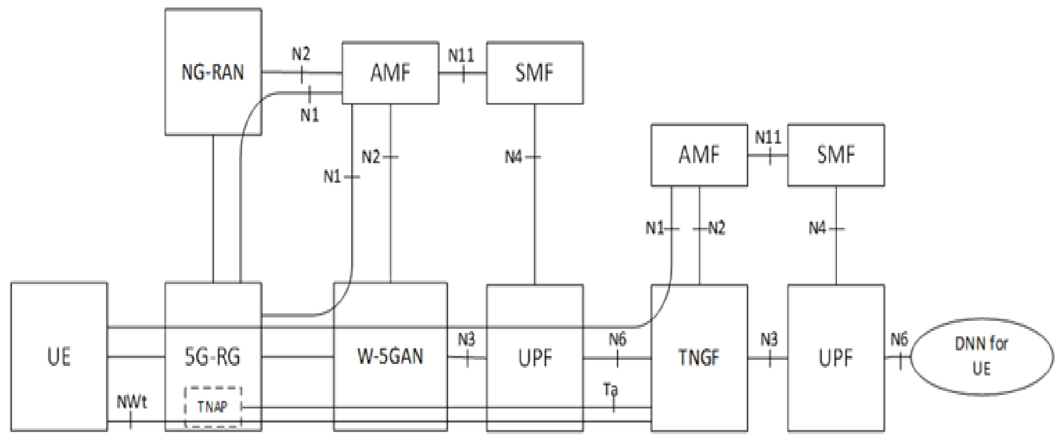

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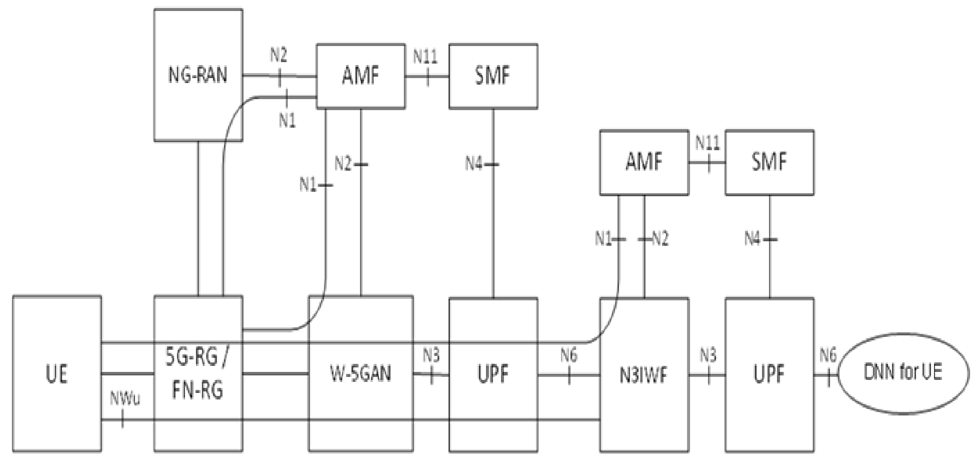

Figure: 5G System Architecture for UE behind 5G-RG and FN-RG using Untrusted N3GPP Access

Management of Service Area Restrictions in Wireline Access

The Subscription Data in the 5G CN for a 5G-BRG includes a Service Area Restriction which may contain either:

- Allowed or
- Non-Allowed Areas specified by using explicit GLI(s) and/or other Geographical Information (e.g., Longitude/Latitude, Zip Code, etc.).'

The Subscription Data in the 5G CN for a 5G-CRG and FN-CRG includes a Service Area Restriction which may contain either Allowed or Non-Allowed Areas specified by using explicit HFC Node IDs and/or other geographical information (e.g., longitude/latitude, zip code, etc.).

The Geographical Information used to specify Allowed or Non-Allowed Area is only managed in the Network, and the Network will map it to a List of GLI(s) or HFC Node IDs before sending Service Area Restriction information to the 5G CN Policy Node.

The 5G CN Node stores the Service Area Restrictions for the 5G-RG or FN-CRG as part of the Subscription Data.

The 5G CN Policy Node in the Serving Network may (e.g. due to varying conditions such as 5G-RG's Location, Time & Date) further adjust Service Area Restrictions of a 5G-RG, either by expanding an allowed Area or by reducing a Non-Allowed Area.

The 5G CN and the Policy Node may update the Service Area Restrictions of a 5G-RG or a FN-CRG at any time.

Upon change of serving AMF due to Mobility, the old AMF may provide the new AMF with the Service Area Restrictions of the 5G-RG that may be further adjusted by the 5G CN Policy node.

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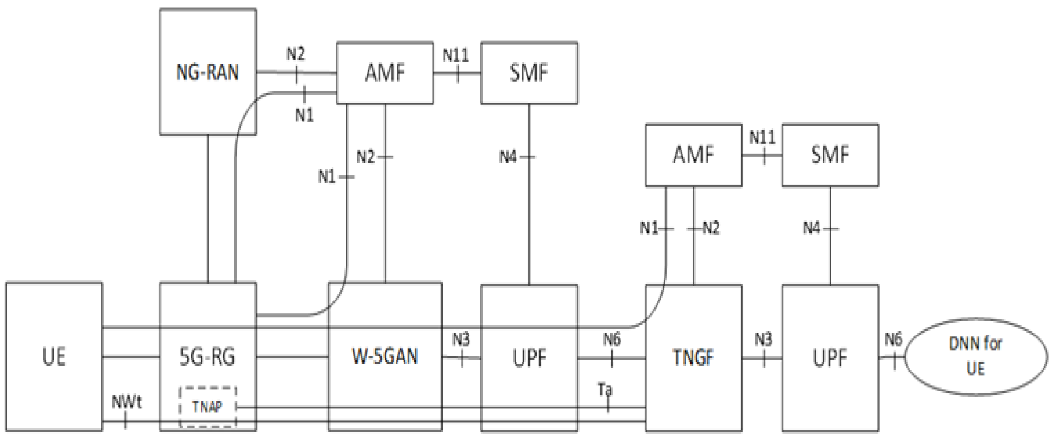

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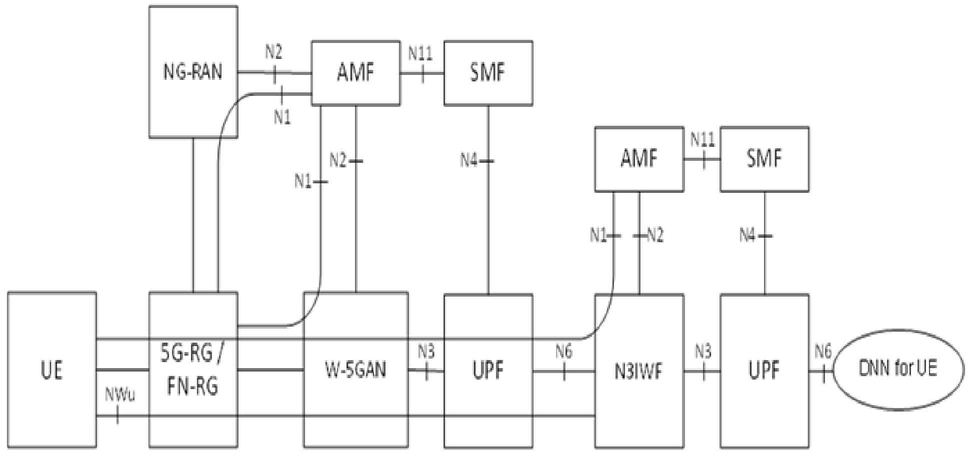

Figure: 5G System Architecture for UE behind 5G-RG and FN-RG using Untrusted N3GPP Access

UE behind 5G-RG and FN-RG

An RG connecting via W-5GAN or NG-RAN Access towards 5GC can provide Connectivity for a UE behind the RG to access an N3IWF or TNGF.

It is assumed that the UE is 5GC capable, i.e. supports un-trusted Non-3GPP Access and/or Trusted Non-3GPP Access.

This allows the RG, W-5GAN and the RG's Connectivity via 5GC to together act as Un-trusted/Trusted N3GPP Access to support UEs behind the RG.

When FN-RG/5G-RG is serving a UE, the Control (CP) & User Plane (UP) Packets of the UE is transported using a FN-RG/5G-RG IP PDU session and then from PSA UPF of that PDU session to an IWF.

A single FN-RG/5G-RG IP PDU session can be used to serve multiple UEs.

The Figure shows the Non-Roaming Architecture for a UE, behind a 5G-RG, accessing the **5GC via TNGF** where the combination of **5G-RG, W-5GAN and UPF serving the 5G-RG is acting as a trusted Non-3GPP access network**.

NOTE 1: *FN-RG and W-5GAN acting as trusted Non-3GPP access is not considered in this specification as it is assumed that FN-RG does not support EAP-5G.*

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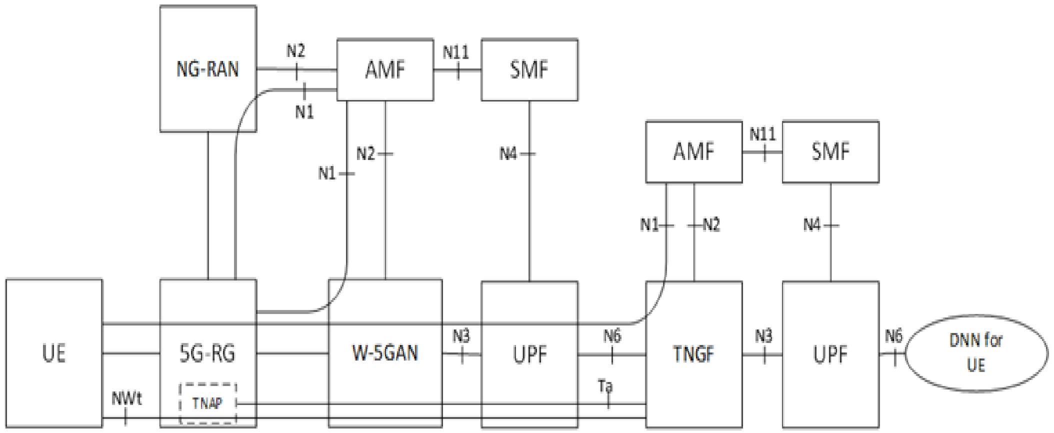

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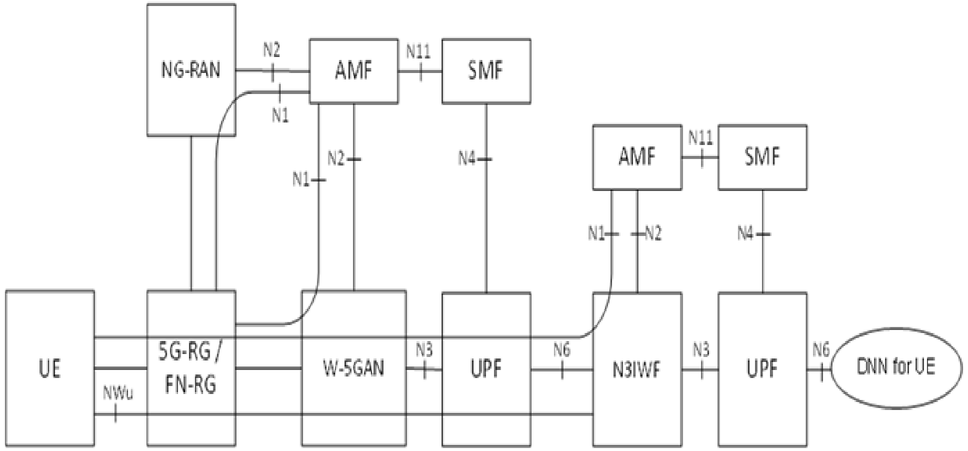

Figure: 5G System Architecture for UE behind 5G-RG and FN-RG using Untrusted N3GPP Access

Non-5G Capable Device behind **5G-CRG** (*5G Cable Residential Gateway*) and **FN-CRG** (*Fixed Network Cable RG*)

For isolated 5G Networks (i.e. Roaming is not considered) with Wireline Access, *Non-5G Capable* (**N5GC**) Devices connecting via **W-5GAN** (*Wireline 5G Access Network*) can be authenticated by the 5GC using EAP based Authentication method(s) as defined in 5GS Security Architecture & Procedure.

In the Figure, the following Call Flow describes the overall Registration procedure of such a Device.

Roaming is not supported for N5GC Devices.

The usage of N5GC Device correspond to a Subscription record in the 5G CN that is separate from that of the CRG.

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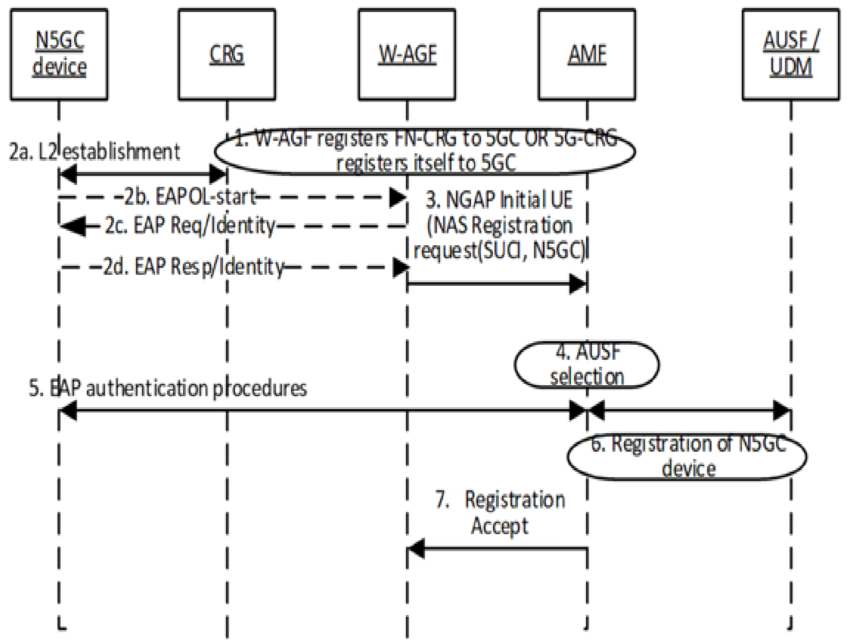

Figure: 5G Core registration of Non-5GC device

1. 5G System Architecture enhancements on Wireless and Wireline Convergence Access support

Differentiated services for NAUN3 (Non Authenticable Non-3GPP) Devices behind 5G-RG

NAUN3 Devices cannot be authenticated by 5GC, but may e.g. be locally authenticated by the 5G-RG using pre-shared secret.

Differentiated Services (QoS, Network Slicing) may be provided for NAUN3 Devices as defined.

NAUN3 Devices may be associated with "Connectivity Group IDs" where each Connectivity Group ID corresponds to a separate Physical or Virtual Port on the 5G-RG.

These ports could, e.g. refer to separate Physical Ethernet Ports and/or to Separate WLAN SSIDs &/or to a separate VLAN.

The devices that connect to a certain logical port are considered part of the same Connectivity Group ID.

Each Connectivity Group ID is then mapped to a separate PDU Session that is established by the 5G-RG based on the procedures defined. The overall Architecture is illustrated in the Figure.

The 5G-RG is configured with the (Virtual) Port Information (e.g. VLANs & SSIDs). The URSP rules can be provided to the RG to indicate how to map Connectivity Group ID to the Parameters of the PDU Session used to carry the traffic of corresponding Devices e.g. DNN, S-NSSAI, etc.

NOTE: *In addition, the mapping between a "virtual port" and DNN/S-NSSAI can be configured.*

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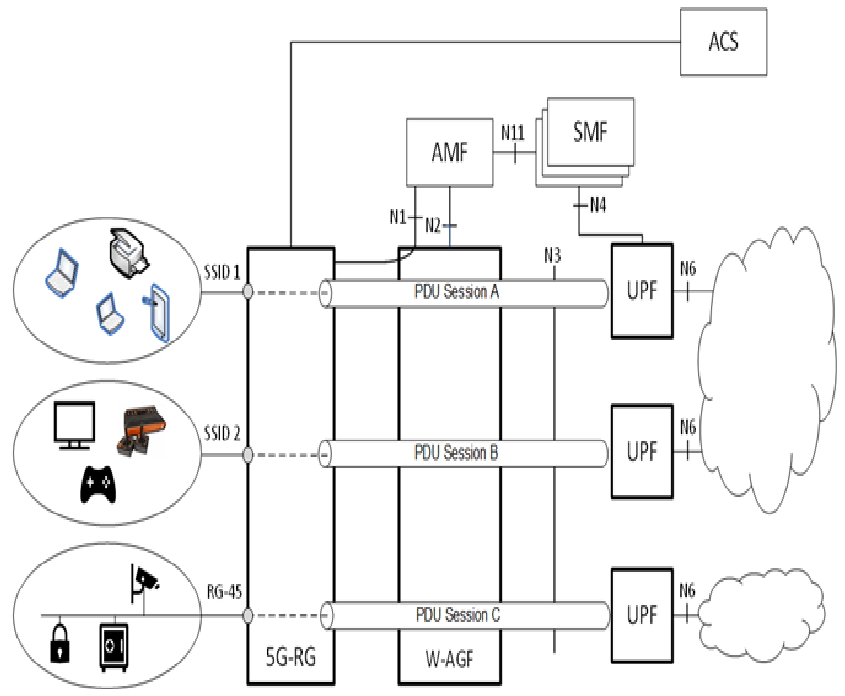

Figure: 5G System Architecture example for NAUN3 devices behind 5G-RG based on Connectivity Groups

Authenticable Non-3GPP **(AUN3)** ***Devices*** **behind 5G-RG**

- Each AUN3 Device has its own 5G CN Subscription Data including its own SUPI & Policy Control Subscription Data.

- In order to serve the AUN3 Device in 5GC, a 5G-RG issues a NAS register & handles RM & CM related Signalling on behalf of an AUN3 Device that it is requesting to be served and relays EAP signalling between the AUN3 Device & the 5GC.

- A 5G-RG serving an AUN3 Device establishes a single PDU Session on behalf on this AUN3 Device.

- A 5G-RG shall be connected to the 5GC (be in RM-REGISTERED & CM-CONNECTED mode) over Wireline Access to serve an AUN3 Device: the 5G-RG shall not issue a NAS register or Service request on behalf of an AUN3 Device if it is itself not registered & connected to the 5GC.

- The 5G-RG is configured with URSP for each AUN3 Devices it serves.

- The AUN3 devices and the 5G-RG belong to the same PLMN.

- There shall be a separate N2 connection per AUN3 Device that is in state CM-CONNECTED.

- The W-CP & W-UP Protocols shall be able to manage Multiple Separate Registrations & PDU Sessions for different SUPIs between the same pair of 5G-RG & W-AGF. In particular, W-CP needs to be able to differentiate NAS messages related to a 5G-RG & to each different AUN3 Device served by this 5G-RG & W-UP needs to distinguish between UP Packets for a 5G-RG & each different AUN3 Device served by this 5G-RG.

- When the registration of an AUN3 Device has successfully completed, the 5G-RG establishes a PDU Session on behalf of the AUN3 Device. This PDU Session is handled by 5GC as part of the AUN3 Subscription & is associated with the SUPI of AUN3 Device. An AUN3 Device can at a given time only use a single PDU Session. The parameters to establish this PDU session are based on the URSP (if any) for the AUN3 device.

- Different QoS Parameters may apply to PDU sessions of different AUN3 Devices.

- Roaming is not applicable to Subscriptions for AUN3 Devices.

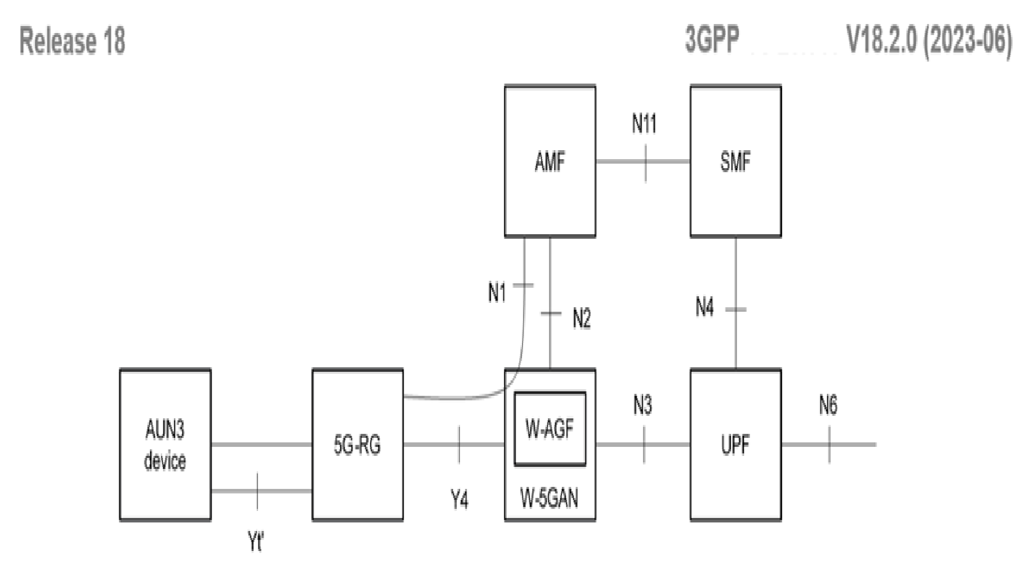

Figure: 5G System Architecture AUN3 Device behind 5G-RG

Non-3GPP Device behind 5G-RG based on 5G System Exposure

The Solution consists of three (3) parts that are used to provide a working End-to-End (E2E) Solution:

1. Example for how non-3GPP device information can be created in an AF.

2. Enhancements to the NEF Exposure Services to provide the non-3GPP Device
   information to 5GC.

3. Description for How the Traffic from Non-3GPP Devices can be identified in the 5GC to
   provide differentiated Charging & QoS.

The overall 5GS Architecture is shown in the Figure. Only the relevant NFs are shown.

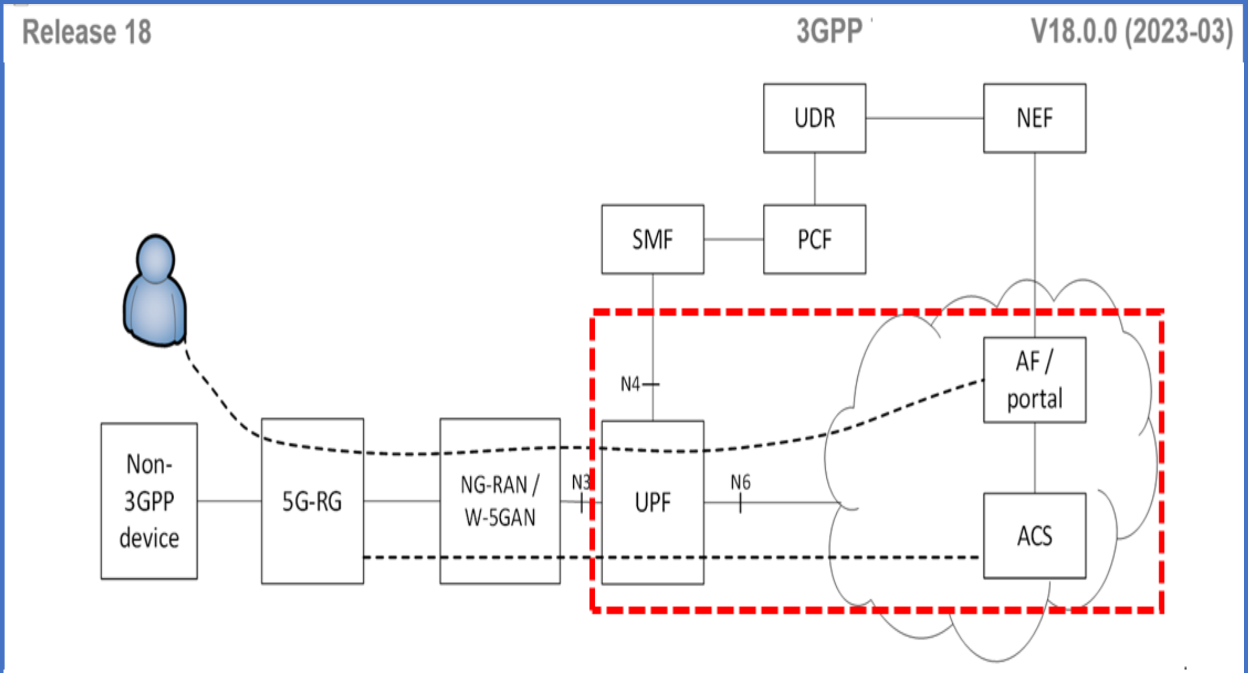

Figure: 5G System Architecture for Non-3GPP Device behind 5G-RG based on 5GS exposure

1. 5G System Architecture enhancements on Wireless and Wireline Convergence Access support

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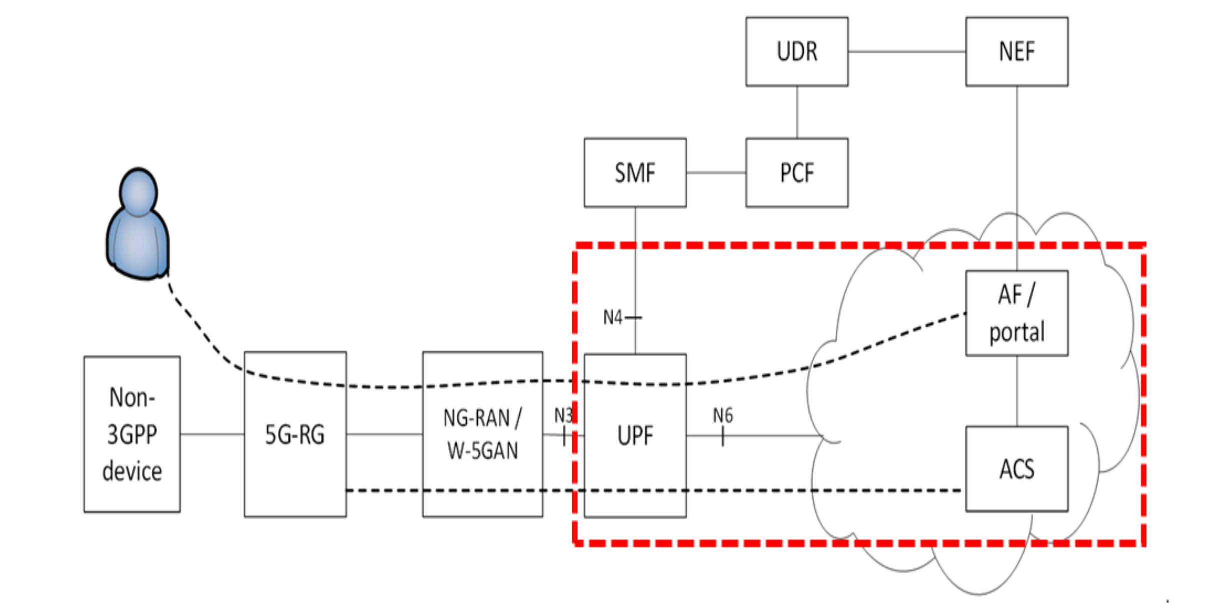

Figure: 5G System Architecture for Non-3GPP Device behind 5G-RG based on 5GS exposure

Non-3GPP Device behind 5G-RG based on 5G System Exposure

Providing Non-3GPP Device information to AF

In this solution, the AF is assumed to have access to Information about the Non-3GPP Devices that are or have been connected behind the RG.

Based on existing BBF specifications, the Auto-Configuration Server (ACS) can retrieve Information about the Non-3GPP Devices from the 5G-RG.

This Information can e.g. contain the Host Table from the DHCP Server in the RG, or Device List gathered by other means, & typically includes for each Device such as:

- Host Name,
- MAC Address of the Device
- IP Address allocated to the Device.

An example of IPv6 LAN Devices Host Table is shown in the Figure.

In the case of IPv4 traffic, the routed RG typically has NAT functionality. The IPv4 addresses in the list of Non-3GPP Devices received from the RG would thus correspond to the Private IPv4 addresses.

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```
IPv6 LAN Devices List
-----------------------------------------------------------------------
Hostname                           MAC Address       IPv6 Address
E-5CG1475XFN                       f4:7b:09:b0:35:c9 2001:b030:2309:0:68d5:35ca:7691:9bb9
Galaxy-S21-5G                      46:15:0f:b6:85:b7 2001:b030:2309:0:4846:9efb:90e5:2466
LAPTOP-8PP10Q5G                    00:f4:8d:d6:34:a7 2001:b030:2309:0:f8f1:e3c5:72e9:233d
Apple-TV                           04:4b:ed:a8:9a:b1 2001:b030:2309:0:ec69:b99d:3260:87f3
Galaxy-Tab-S2                      c0:d3:c0:b9:4d:73 2001:b030:2309:0:b8e2:cc2f:dde2:d0f3
Stefan--iPhone                     c6:71:15:15:97:71 2001:b030:2309:0:987:7bf7:9993:dd97
```

Figure: Example of IPv6 LAN Devices Host Table from 5G-RG

Non-3GPP Device behind 5G-RG based on 5G System Exposure

Providing Non-3GPP Device information to AF

The existing 5G CN NEF Service Parameter Service is enhanced with a new Service Description to allow an AF to provide the Non-3GPP Device information to 5GC.

This information will be used by 5GC to detect the Traffic to/from a Non-3GPP Device & also to provide Differentiated QoS &/or Charging.

The information provided by the AF via the Nef_ServiceParameter Service contains:
- GPSI of the RG.
- List of Non-3GPP Devices, containing for each device:
- IPv6 Address or IPv4 & the Port number of the Device.
- Device Profile ID.

The 5G CN NEF maps the RG's GPSI to the RG's SUPI & stores the Non-3GPP Device information in 5G CN as Application Data, as currently defined for Nnef_ServiceParameter Service in 5GS Architecure Procedures.

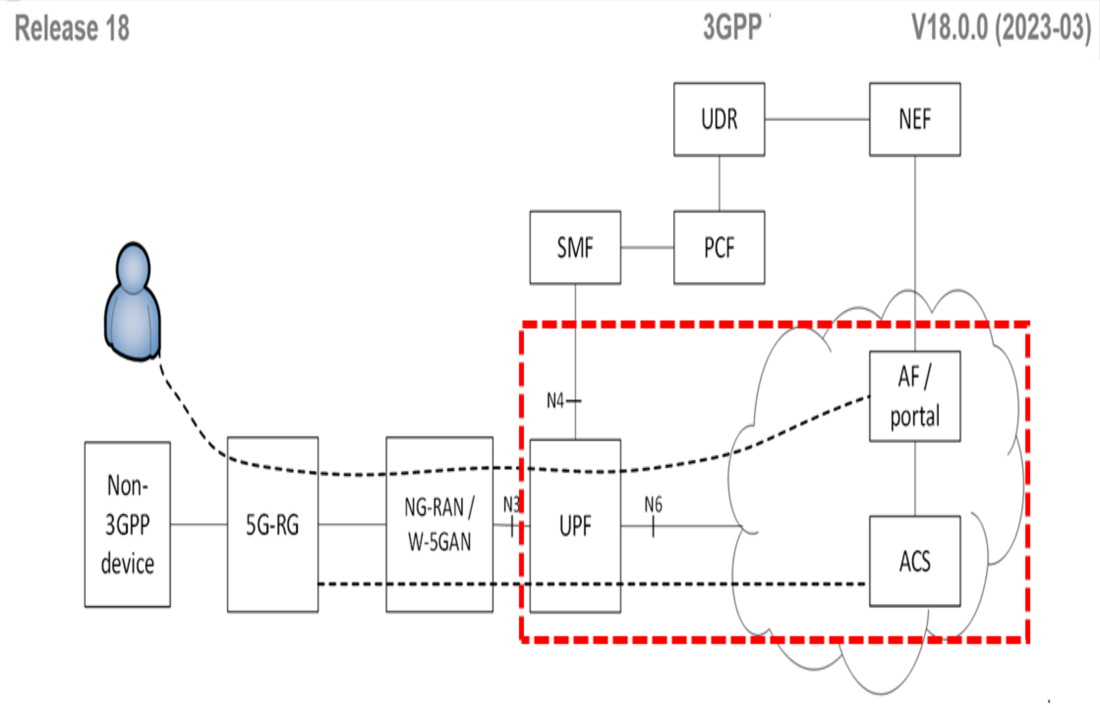

Figure: 5G System Architecture for Non-3GPP Device behind 5G-RG based on 5GS exposure

Non-3GPP Device behind 5G-RG based on 5G System Exposure

Providing Non-3GPP Device information to AF

Differentiated Services per Non-3GPP Device

When a PDU Session for an RG is established, the PCF contacts the UDR to subscribe to Application Data that may be available, as per existing procedure for Service specific Parameter Provisioning.

The PCF thus receives the Non-3GPP Device Information from UDR corresponding to the RG's SUPI.

The PCF takes the Service Parameters as well as other information (e.g. RG's Subscribed QoS & RG's Policy Subscription Data in UDR) into account for Policy decisions, e.g. to determine QoS & Charging Parameters for the Non-3GPP Device's Traffic.

The PCF may provide PCC rules to SMF that are specific for individual Non-3GPP Devices, containing SDF Filter with the IPv6 address or IPv4 and the Port number of the Device, and corresponding QoS & Charging related parameters.

The PCF may provide different PCC rules for different Services, as per existing Standards.

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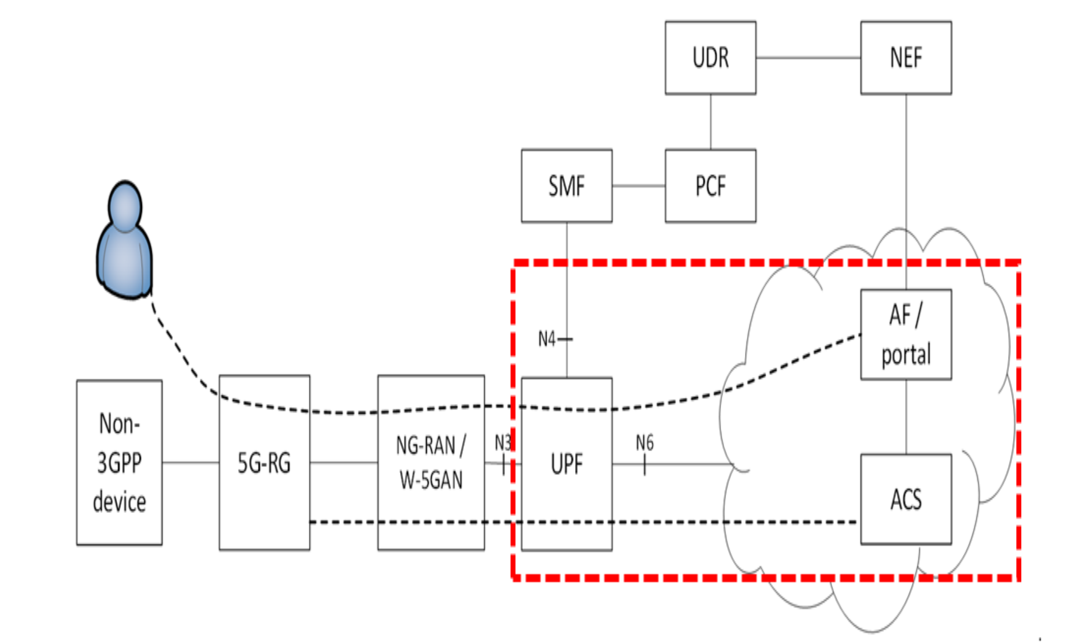

Figure: 5G System Architecture for Non-3GPP Device behind 5G-RG based on 5GS exposure

1. 5G System Architecture enhancements on Wireless and Wireline Convergence Access support

Control Plane (CP) Protocol Stacks for W-5GAN (Wireline 5G Access Network)

Control Plane Protocol Stacks between the 5G-RG and the 5GC AMF is shown in the Figure.

For W-5GBAN, the W-CP Protocol stack between 5G-BRG & W-AGF is defined by BBF.

For W-5GCAN, the W-CP protocol stack between 5G-CRG and W-AGF is defined in WR-TR-5WWC-ARCH.

The Protocol Stack between 5GC/AMF & W-AGF is defined in the 5GS Architecture.

The W-CP Protocol Stack:
- supports transfer of NAS signalling between the 5G-RG & the W-AGF;
- supports to carry AS Parameters (e.g. SUCI or 5G-GUTI, Requested NSSAI & Establishment Cause) and NAS packets;
- supports the setup, modification and removal of at least one W-UP Resource per PDU session;
- may support the Setup, Modification & Removal of Multiple W-UP Resources per PDU session.

For the 5G-RG connected via NG-RAN the Protocol Stack defined in the 5GS Architecture applies with UE corresponding to 5G-RG.

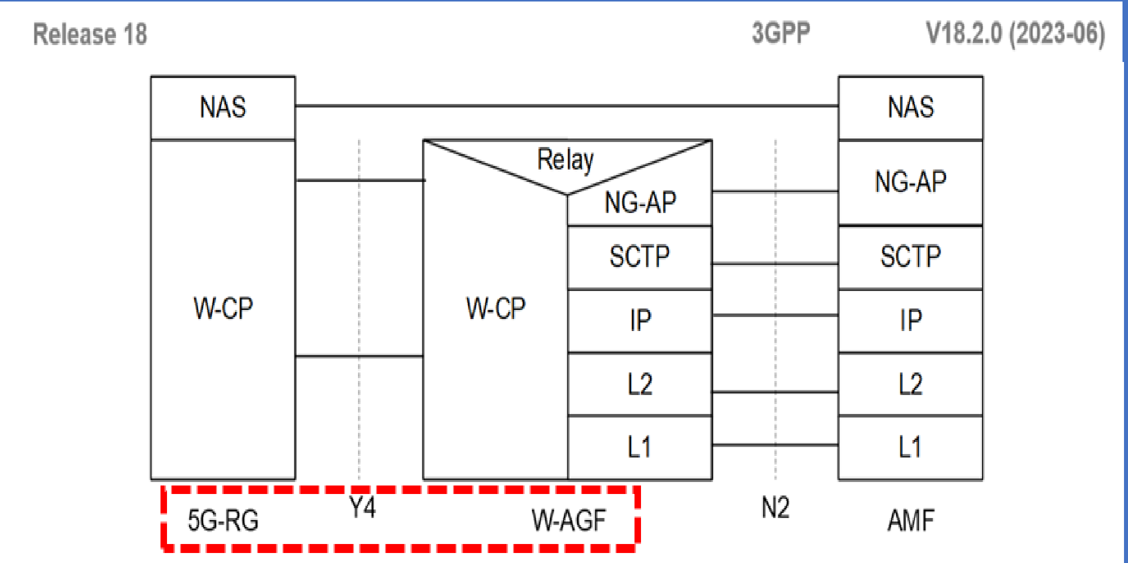

Figure: 5G System Architecture Control Plane (CP) stack for W-5GAN for 5G-RG

Control Plane (CP) Protocol Stacks between the FN-RG and the 5GC

The CP Protocol Stack between FN-RG & AMF is shown in the Figure.

The W-AGF acts as an N1 termination point on behalf of FN-RG.
For W-5GBAN, the L-W-CP Protocol Stack, between FN-BRG & W-AGF is defined by BBF.

For W-5GCAN, the L-W-CP Protocol Stack between FN-CRG & W-AGF is defined in WR-TR-5WWC-ARCH.

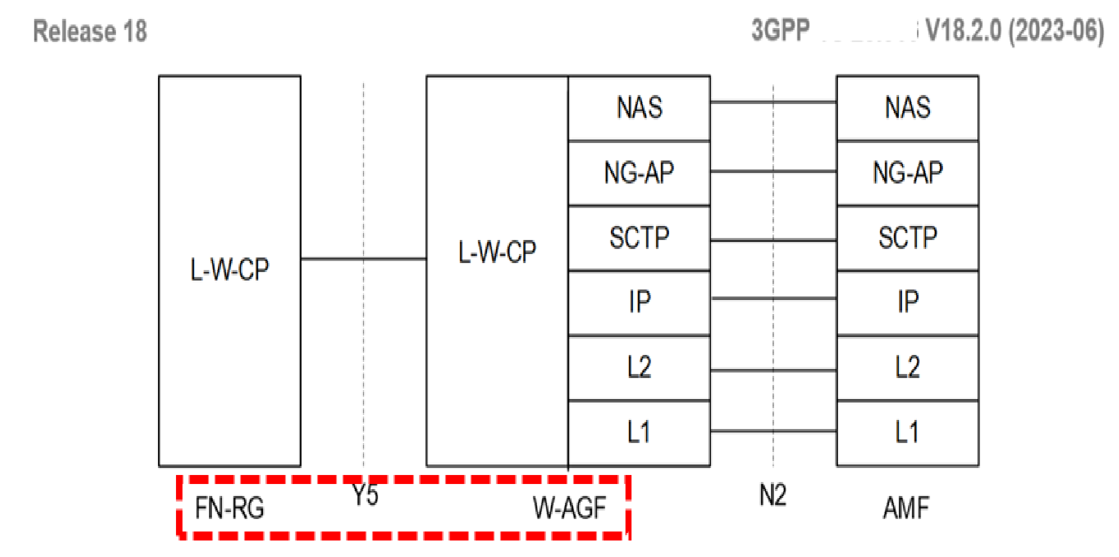

Figure: 5G System Architecture Control Plane (CP) stack for W-5GAN for FN-RG

1. 5G System Architecture enhancements on Wireless and Wireline Convergence Access support

User Plane Protocol Stacks for W-5GAN (Wireline 5G Access Network)

User Plane (UP) Protocol Stacks between the 5G-RG and the 5GC UPF is shown in the Figure.

For W-5GBAN, the W-UP protocol stack between 5G-BRG and W-AGF is defined by BBF.

For **W-5GCAN** (*Wireline 5G Cable Access Network*), the W-UP Protocol Stack between 5G-CRG & W-AGF is defined in WR-TR-5WWC-ARCH.

The Protocol Stack between 5GC/UPF & W-AGF is defined in the 5GS Architecture.

For the W-UP Protocol Stack:

- W-UP supports at least one (1) W-UP Resource per PDU session. This will be the default W-UP resource.
- W-UP may support multiple W-UP resources per PDU session and associate different QoS profiles (QFIs) to different W-UP resources.
- W-UP supports transmission of Uplink (UL) & Downlink (DL) PDUs.
- W-UP supports Access specific QoS Parameters that can be mapped from 3GPP QoS Parameters (e.g.5QI, RQI) received from the 5GC.

For the 5G-RG connected via NG-RAN the protocol stack defined in the 5GS Architecture applies with 5G-RG replacing the UE.

Release 18 3GPP V18.2.0 (2023-06)

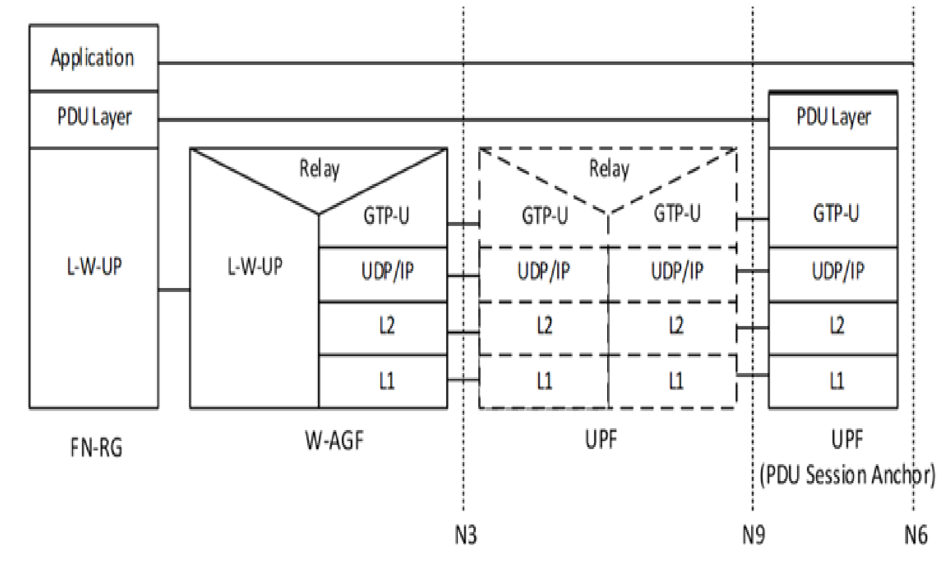

Figure: 5G System Architecture User Plane (UP) stack for W-5GAN for FN-RG

Annex 1: 5G PINs (Personal IoT Networks) and 5G CPNs (Customer Premises Networks)

Personal IoT Networks (PINs) and Customer Premises Networks (CPNs) provide local connectivity between UEs and/or Non-3GPP Devices.

The CPN via an eRG, or in 5G PINs with PIN Elements (PINEs) via a PIN Element with Gateway Capability (PEGC) can provide access to 5G Network Services for the UEs and/or Non-3GPP Devices on the CPN or PIN.

CPNs and PINs have in common that, in general, they are:
- owned, Installed and/or (at least partially) Configured by a Customer of a Public Network Operator.

A Customer Premises Network (CPN) is a Network located within
- a Premises (e.g. a Residence, Office or Shop).
- via an evolved Residential Gateway (eRG), the CPN provides connectivity to the 5G Network. The eRG can be connected to the 5G Core Network via wireline, wireless, or hybrid access.
- A *Premises Radio Access Station* (**PRAS**) is a Base Station installed in a CPN. Through the PRAS, UEs can get Access to the CPN and/or 5G Network Services.

The **PRAS** can be configured to use
- Licensed,
- Unlicensed, or
- Both Frequency bands.

Connectivity between the **eRG** and the **UE**, **non-3GPP Device**, or **PRAS** can use any suitable **Non-3GPP Technology** (e.g. **Ethernet, optical, WLAN).**

A Personal IoT Network (PIN) consists of **PIN Elements (PINEs)** that communicate using PIN
- "Direct Connection" or
- "Direct Network Connection

and is managed locally using a PIN Element (PINE) with Management Capability (PEMC).

Examples of PINs include Networks of Wearables and Smart Home / Smart Office Equipment.

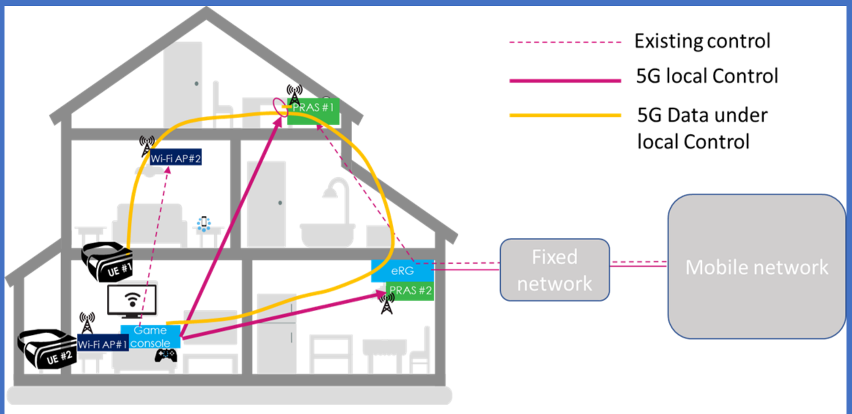

Figure: 5G Local Control of Premise Radio Access Stations (PRASs) for UE to access CPN Device

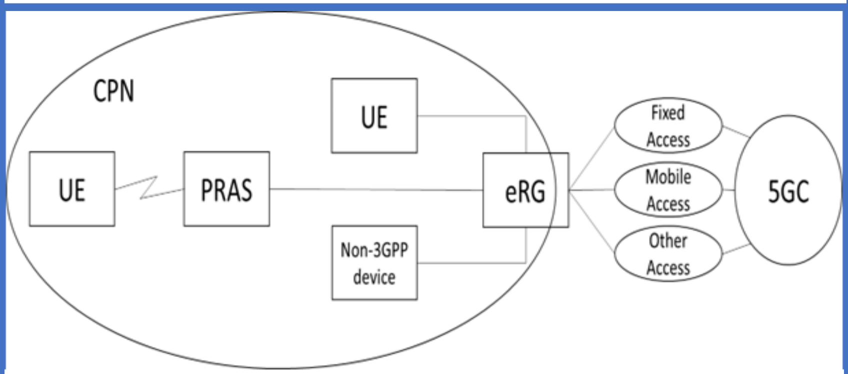

Figure: Customer Premises Network (CPN) connected to 5GC

Vodafone unveils Open RAN 5G network-in-a-box

Feb 17, 2023

Vodafone's Yago Tenorio shows off the operator's 5G network-in-a-box.

- Vodafone has unveiled a new mini 5G network the size of a Wi-Fi router
- It has a core and radio software, a mini computer and a software-defined radio chipset
- It is just a prototype currently
- But if offered as a product could revolutionise the 5G private network sector

Annex 2: Mobile Networks to evolve from:

a 2G, 3G, 4G Design that offers "Best-effort" Services

to

a Design that offers Performance and User Experience Guarantees

=>

Capabilities related to e.g.:

When a *Multi-access* (**MA**) **PDU Session** is established, the Network may provide the UE with *Measurement Assistance Information* to enable the UE in determining which measurements shall be performed over both Accesses, as well as whether measurement reports need to be sent to the Network.

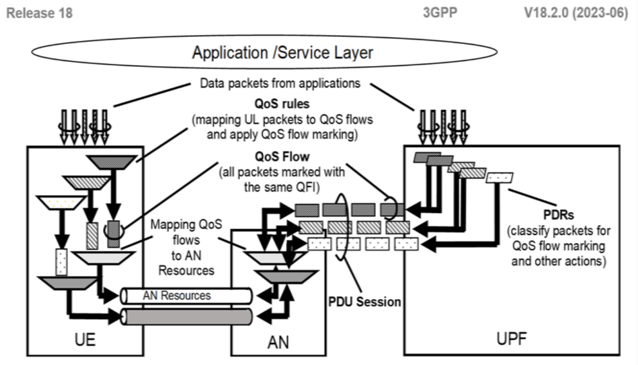

Figure: The 5G Principle for Classification and User Plane (UP) marking for QoS Flows and mapping to AN Resources

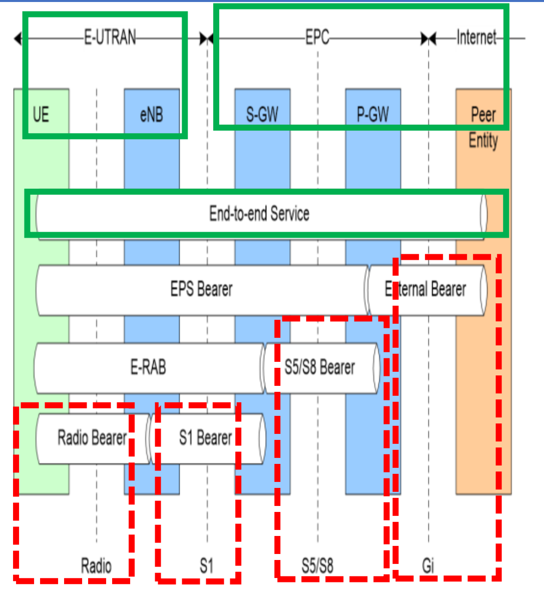

Figure : EPS Bearer Service Architecture

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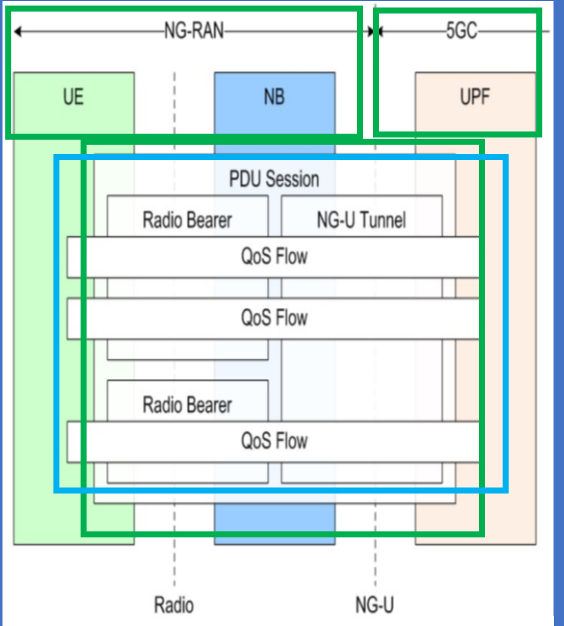


Figure: 5G CN NG-RAN Bearer Services QoS Architecture

Measurement Assistance Information shall include the addressing information of *a Performance Measurement Function* (**PMF**) in the UPF, the UE can send PMF protocol messages incl.:

- Messages to allow for *Round Trip Time* (**RTT**) Measurements: the "*Smallest Delay*" steering mode is used or when either "*Priority-based*", "*Load-Balancing*" or "**Redundant**" steering mode is used with RTT threshold value being applied;
- Messages to allow for *Packet Loss Rate* (**PLR**) measurements, i.e. when steering mode is used either "*Priority-based*", "*Load-Balancing*" or "*Redundant*" steering mode is used with **PLR** threshold value being applied;
- Messages for reporting Access Availability/Un-availability by the UE to the UPF.
- Messages for sending **UE-assistance Data** to **UPF.**
- Messages for sending "*Suspend Traffic Duplication*" and "*Resume Traffic Duplication*" from **UPF** to **UE** to "suspend" or "resume" traffic duplication as defined in **5GS Architecture.**

Annex 3: 5G Architecture for Hybrid and Multi-Cloud Environments

The Main Challenges to overcome in a Hybrid & Multi-Cloud Strategy are:

1. Maintaining Portability; 2. Controlling the Total Cost of Ownership (TCO); 3. Optimizing Productivity & Time to Market (TTM).

DevOps – *a Set of Practices* that brings together *SW Development & IT operations* with the Goal of Shortening the Development & Delivery Cycle & increasing SW Quality **- is** often thought of and discussed **in the Context of a Single Company or Organization. The Company usually Develops the SW, Operates it & Provides it as a Service to Customers,** according to the **SW-as-a-Service (SaaS) Model. Within this context**, it is easier to have **Full Control over the Entire Flow**, including **Full Knowledge of the Target Deployment Environment.**

In the **Telecom Space**, by contrast, we typically follow the **"as-a-Product (aaP) Business model**, in which **SW is developed by Network SW Vendors** e.g. as Ericsson (Nokia, Huawei, ZTE) & provided to Communication Service Providers (CSPs) that Deploy & Operate it within their Network. This **Business Model requires the consideration of additional aspects**.

The most important contrasts between the Standard DevOps SaaS Model & the Telecom aaP Model are the **Multiplicity of Deployment Environments & the fact the Network SW Vendor Development Teams cannot know upfront exactly what the Target Environment looks like**.

Although a SaaS Company is likely to Deploy & Manage its SW on two (2) or more different Cloud Environments, **this is inevitable within Telco**, as each CSP creates &/or selects its own Cloud infrastructure (Fig. 1 below).

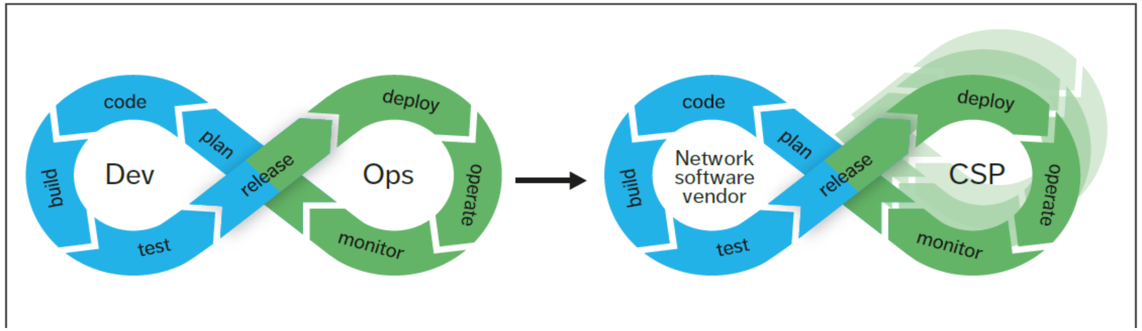


Figure 1: The DevOps and (Telecom) aaP Business Models

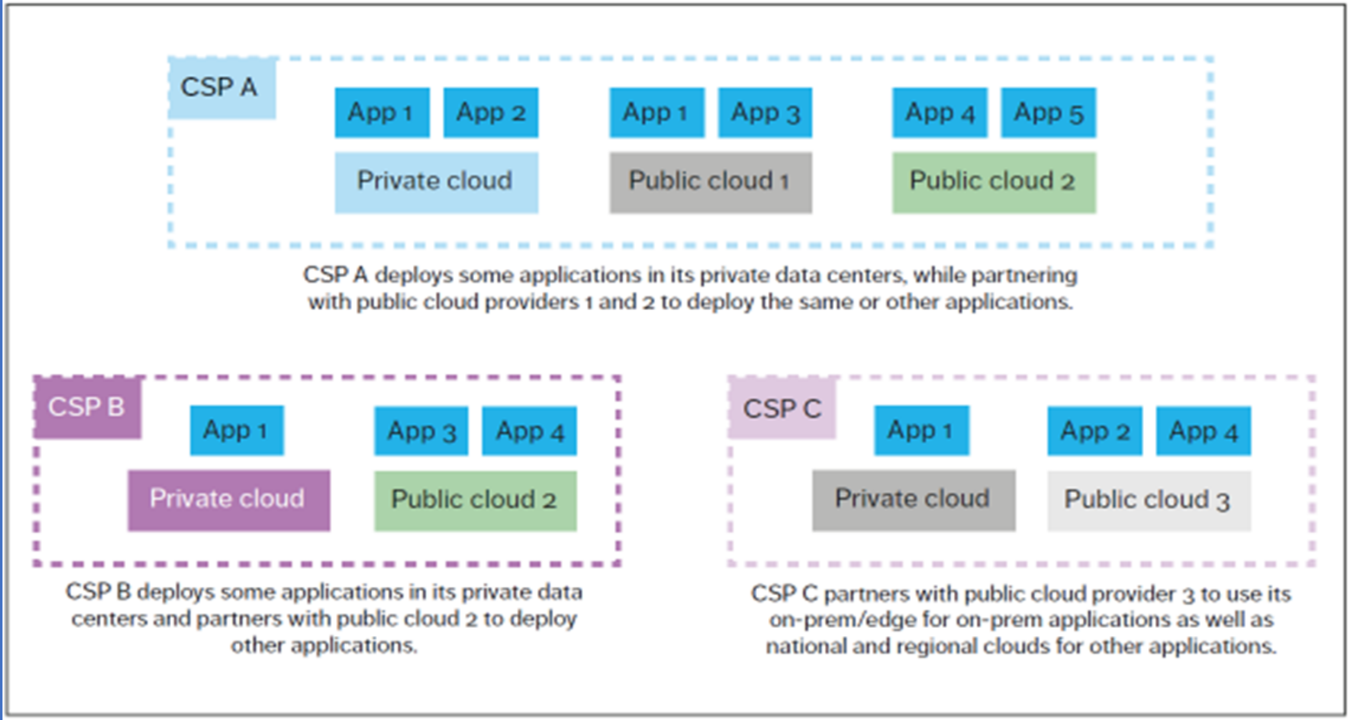


Figure 2: Examples of Hybrid and Multi-Cloud Deployment Scenarios that Applications must be able to support

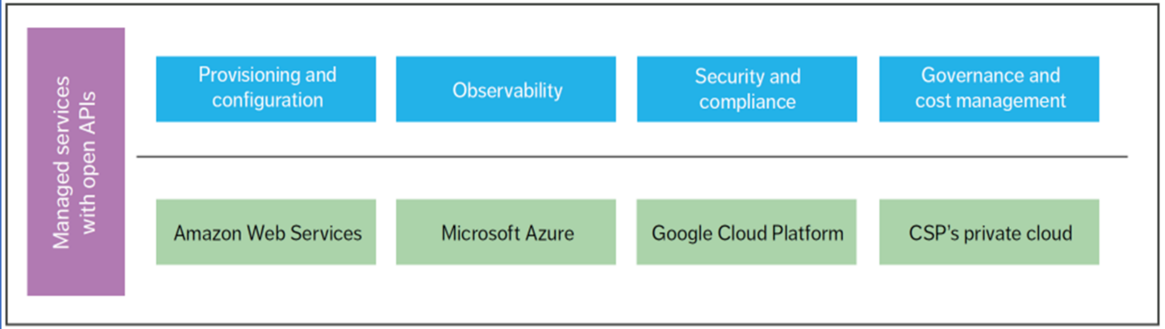


Figure 3: Key Enablers for a Multi-Cloud Native Application

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

1. 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

2. 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)*

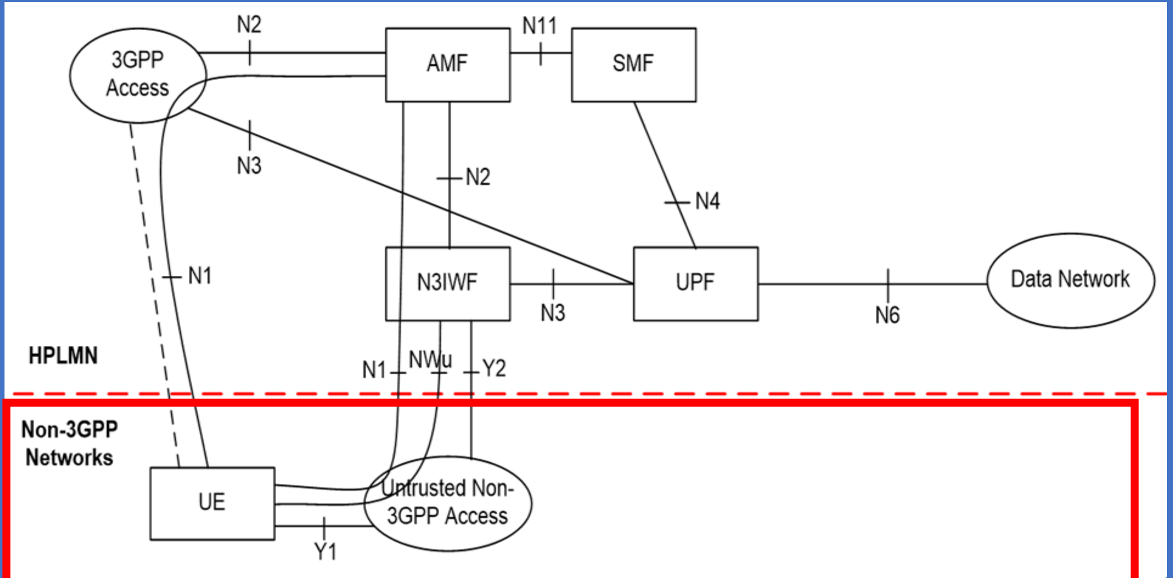


Fig. 1-1 Non-Roaming Architecture for 5G Core Network with Untrusted Non-3GPP Access

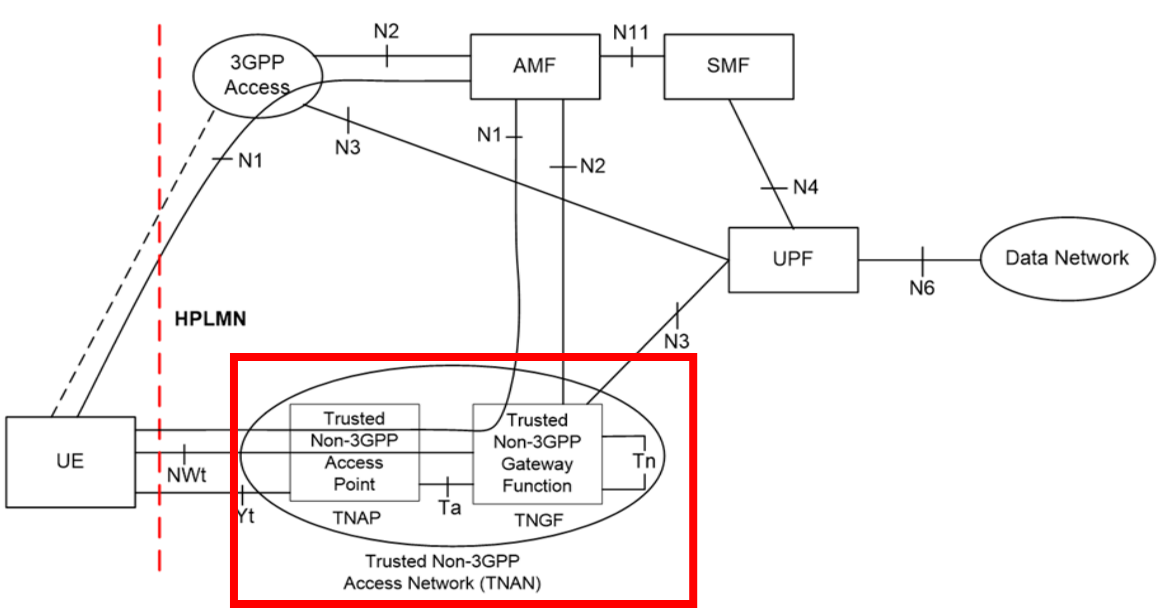
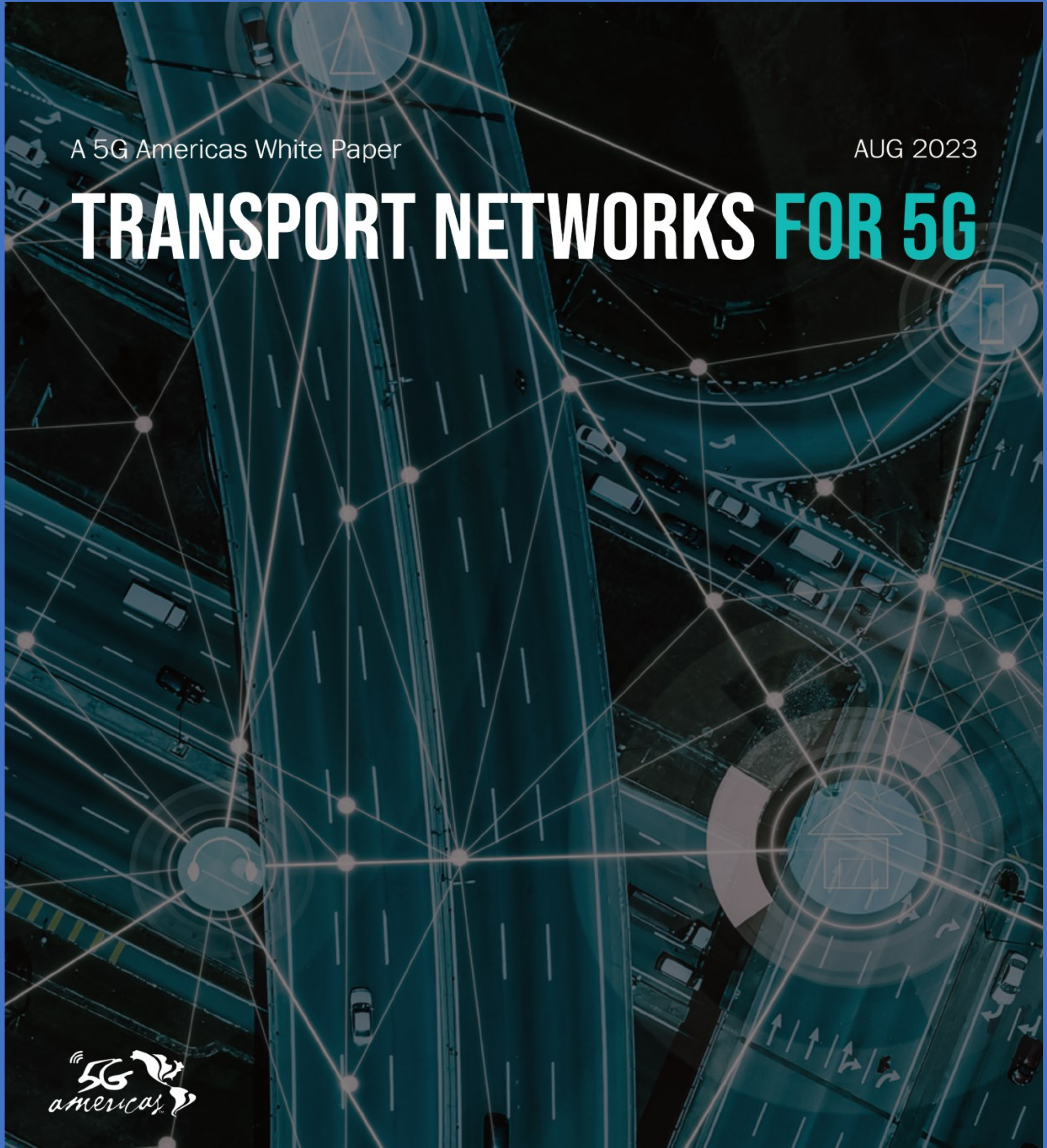


Fig. 1-2 Non-Roaming Architecture for 5G Core Network with Trusted Non-3GPP Access

Annex 5. Transport Networks in 5G, 5G Americas WP, Aug., 2023



3. Where Things are Going: 5G Deployment and Wireline/Wireless Convergence

A significant amount of mobile traffic is generated and consumed indoors. As such, Indoor RAN deployments are increasingly becoming part of an overall MNO densification strategy for coverage extension and private networks driven by enterprise digitalization and industry 4.0 use cases. Deploying some mid- and high-band spectrum inside buildings creates a range of concerns for MNOs due to factors including free-space loss, penetration loss, reflection, refraction, and various forms of fading.

Another main issue is the backhaul connection from buildings to the MNO packet core. Since buildings can have a wide range of WAN connection types from a variety of ISPs, this variability adds risk in terms of RAN performance, security, OA&M and resiliency. This is defined as untrusted backhaul.

The good news for 5G systems is that the TS 33.501 3GPP standard specifies a security architecture, i.e., the security features and the security mechanisms for the 5G system and the 5GC, and the security procedures performed within the 5G system. The main concern for the transport network is to enable a secure connection from the UE to the 5G Core control plane.

As we know from LTE, IPSec VPNs from baseband to packet core SecGW (where required) are the de facto approach to securing the S1/X2 RAN interfaces. This will persist with 5G backhaul. What's new, and under study now, is how to find the right balance between performance and security for the new packet fronthaul and midhaul interfaces (eCPRI and F1). Fronthaul traffic is bandwidth-intensive and latency-sensitive. Applying IPSec tunnels in a centralized RAN architecture may negatively impact RAN performance. This issue may not be as critical for the F1 interface but needs further study as virtual RAN architectures make their way into the indoor RAN environment.

As RAN technology begins to consider Terahertz spectrum for 6G, the trade-off between performance and security will become increasingly important.

A different future angle is set out in the Broadband Forum's Wired Wireless Convergence work formerly known as Fixed-Mobile Convergence. Briefly summarizing, this allows fixed networks to re-use the authentication and subscriber management functions such as UPF from the wireless core, eliminating duplication of investment and operations—allowing consistent subscriber management and operations across the two domains, while also bringing the sophistication of the 5G QoS and service model into the wired domain.

3.1 5G Deployment and Sustainability

In the 5G ecosystem sustainability initiatives are part of every organization's agenda including telecom service providers, telecom equipment providers and telecom standards bodies. Recently, the International Telecom Union (ITU) published guidance (ITU-T L.1471) for information and communications technology organizations on how to set net-zero emission targets. The initiative also defined innovation projects to improve energy efficiency and reduce emissions. The GSM Association (GSMA), which represents the interests of mobile operators worldwide, was one of the first to embrace the vision and shared commitment to help mobile industry to achieve net-zero emissions by 2050. To support such initiatives, mobile operators in North America have entered into green power partnership agreements to significantly increase the use of renewable electricity in telecom.

Energy is a major expense for telecom operators and reducing greenhouse gases (GHG) makes sense financially. 5G standards have more advanced features than previous generation networks to efficiently use power. artificial intelligence (AI) and predictive analysis could be used to manage the complexity and density of 5G traffic to efficiently adjust power consumptions and improve overall performance. Network monitoring and management tools are evolving to measure energy efficiency key performance indicators (KPIs) to drive the net-zero emissions initiatives and meet sustainability goals.

Remarks & Questions?