Technical Report

TR-456

AGF Functional Requirements

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Executive Summary

This document contains the functional requirements of the Access Gateway Function (AGF), a key mediation function specified by BBF in the 5G Wireline Wireless Convergence (WWC) architecture for Fixed Mobile Convergence (FMC), jointly defined by 3GPP and BBF.

The 5G WWC architecture includes the set of functions and interfaces that realizes the use cases targeted by the BBF and 3GPP for the 3GPP Release 16, including network functions for adapting wireline access to the 5G-Core.

The Access Gateway Function is a logical function deployed between the physical access media (e.g., DSL, PON, GE) in the wireline access network and the 5G core network.

Functional requirements specified for the AGF in this document cover the deployment scenarios described in TR-470 [9]. Both Fixed Network-Residential Gateway (FN-RG) as well as 5G-Residential Gateway (5G-RG) devices are supported.

1 Purpose and Scope

1.1 Purpose

In 2017-2018, the BBF WWC Work Area studied 5G Fixed Mobile Convergence and its impacts on interfaces being defined by 3GPP for release 16 and further releases. BBF concluded its study by December 2018. It resulted in series of liaisons with requests from BBF to 3GPP SA2. Those requests have been considered in the normative phase of 3GPP R16. The Access Gateway Function (AGF) that resides between fixed access networks and the 5G core network, serving both 5G-RG as well as FN-RG, will be described in this document.

1.2 Scope

The scope of this Technical Report is to describe the functional requirements of the AGF. The Access Gateway Function resides in between the aggregation network of fixed access nodes such as DSLAMs and PON OLTs, and the 5G core network. As such subscribers served by access equipment specified in TR-101 issue 2, TR-156 issue 4, TR-167 issue 3, TR-178 issue 2 and TR-301 issue 2 corr1 can be connected to the 5GC via an AGF. The AGF integrates a subset of BNG functions and new functions that together can allow it to serve both FN-RG and 5G-RG. In the current issue of this document, wholesale deployment scenarios (excluding third-party access networks); IPTV; considerations on AGF virtualization and deployment of virtual AGF; are all out of scope. They may be studied in future revisions of the document.

In addition, for the current issue of this document, the only VLAN model on the V interface (as per TR-101) that is considered for 5G-RG is 1:1 double tag. 1:1 single tag and n:1 for 5G-RG are for further study.

Hybrid access is out of scope for this version of the document: only an RG with wireline access is considered here.

Multiple PDU session support for FN-RGs and FN-RG Authentication using PPP Authentication (PAP or CHAP) by 5G Control Plane are both out of scope and are under consideration for a next revision of the document.

CUPS for the AGF will be addressed by WT-458. For this issue of TR-456, the AGF is assumed to be an integrated implementation and the exact call flows between the AGF-CP and AGF-UP are FFS. The impact in WT-458 on these flows will be reflected in subsequent issues of this specification.

2 References and Terminology

2.1 Conventions

In this Technical Report, several words are used to signify the requirements of the specification. These words are always capitalized. More information can be found be in IETF RFC 2119 [35] and RFC 8174 [52].

MUST	This word, or the term “REQUIRED”, means that the definition is an absolute requirement of the specification.
MUST NOT	This phrase means that the definition is an absolute prohibition of the specification.
SHOULD	This word, or the term “RECOMMENDED”, means that there could exist valid reasons in particular circumstances to ignore this item, but the full implications need to be understood and carefully weighed before choosing a different course.
SHOULD NOT	This phrase, or the phrase "NOT RECOMMENDED" means that there could exist valid reasons in particular circumstances when the particular behavior is acceptable or even useful, but the full implications need to be understood and the case carefully weighed before implementing any behavior described with this label.
MAY	This word, or the term “OPTIONAL”, means that this item is one of an allowed set of alternatives. An implementation that does not include this option MUST be prepared to inter-operate with another implementation that does include the option.

2.1.1 Special Convention for this document

Throughout this document, the AGF requirements that are common for a 5G-RG and a FN-RG use the template [R-1], …, [R-x].

The extra AGF requirements needed for the FN-RG use the template [R-FN-1], …, [R-FN-x].

The extra AGF requirements needed for the 5G-RG use the template [R-5G-1], …, [R-5G-x].

In case a given AGF only supports 5G-RG, then this AGF MUST support all requirements [R-1], …, [R-x] AND [R-5G-1], …, [R-5G-x].

In case a given AGF only supports FN-RG (in the example an operator would want to keep FN-RGs while still being able to connect to the 5GC) then this AGF MUST support all requirements [R-1], …, R-x] AND [R-FN-1], …, [R-FN-x].].

In case a given AGF supports both 5G-RG and FN-RG, then this AGF MUST support all requirements [R-1], …, R-x] AND [R-FN-1], …, [R-FN-x] AND [R-5G-1], …, [R-5G-x].

2.2 References

The following references are of relevance to this Technical Report. At the time of publication, the editions indicated were valid. All references are subject to revision; users of this Technical Report are therefore encouraged to investigate the possibility of applying the most recent edition of the references listed below.

A list of currently valid Broadband Forum Technical Reports is published at www.broadband-forum.org.

Document	Title	Source	Year
[1] TR-069 Amendment 6	CPE WAN Management Protocol	BBF	2018
[2] TR-181 Issue 2 Amendment 14	Device Data Model for TR-069	BBF	2020
[3] TR-101 Issue2	Migration to Ethernet-Based Broadband Aggregation	BBF	2011
[4] TR-177 Corrigendum 1	IPv6 in the context of TR-101	BBF	2017
[5] TR-178 Issue 2	Multi-service Broadband Network Architecture and Nodal Requirements	BBF	2017
[6] TR-124 Issue 6	Functional Requirements for Broadband Residential Gateway Devices	BBF	2020
[7] TR-146	Subscriber Sessions	BBF	2013
[8] TR-187 Issue 2	IPv6 for PPP Broadband Access	BBF	2013
[9] TR-470	5G Wireless Wireline Convergence Architecture	BBF	2020
[10] WT-458	CUPS for WWC	BBF	2020
[11] TS 24.501	Non-Access-Stratum (NAS) protocol for 5G System (5GS); Stage3	3GPP	For R16
[12] TS 24.502	Access to the *3GPP* 5G Core Network (5GCN) via non-*3GPP* access networks	3GPP	For R16
[13] TS 38.331	NR; Radio Resource Control (RRC); Protocol specification.	3GPP	For R16
[14] TS 38.410	NG-RAN, NG general aspects and principles	3GPP	For R16
[15] TS 38.412	NG-RAN, NG signaling transport	3GPP	For R16
[16] TS 38.413	NG-RAN; NG Application Protocol (NGAP)	3GPP	For R16
[17] TS 29.303	Domain Name System Procedures	3GPP	For R16
[18] TS 29.413	Application of the NG Application Protocol (NGAP) to non-3GPP access	3GPP	For R16
[19] TS 29.502	5G System; Session Management Services; Stage 3	3GPP	For R16
[20] TS 29.510	5G System; Network function repository services; Stage 3	3GPP	For R16
[21] TS 38.414	NG-RAN; NG data transport	3GPP	For R16
[22] TS 38.415	PDU Session User Plane Protocol	3GPP	For R16
[23] TS 23.316	Wireless and wireline convergence access support for the 5G System	3GPP	For R16

[24] TS 23.003	Numbering, addressing and identification	3GPP	For R16
[25] TS 33.501	Security architecture and procedures for 5G system	3GPP	For R16
[26] TS 23.501	System architecture for the 5G System (5GS)	3GPP	For R16
[27] TS 23.502	Procedures for the 5G System (5GS)	3GPP	For R16
[28] TS 23.503	Policy and charging control framework for the 5G System (5GS); Stage 2	3GPP	For R16
[29] IETF Internet draft draft-allan-5g-fmc-encapsulation	"5G Wireless Wireline Convergence User Plane Encapsulation (5WE)", IETF, March 2020	IETF	2020
[30] IEEE 802.1Q	Virtual Bridged Local Area Networks	IEEE	2018
[31] RFC 1332	The PPP Internet Protocol Control Protocol (IPCP)	IETF	1992
[32] RFC 1570	PPP LCP Extensions	IETF	1994
[33] RFC 1877	PPP IPCP Extensions	IETF	1995
[34] RFC 1994	PPP Challenge Handshake Authentication Protocol (CHAP)	IETF	1996
[35] RFC 2119	Key words for use in RFCs to Indicate Requirement Levels	IETF	1997
[36] RFC 2153	"PPP Vendor Extensions", IETF Informational Standard, May 1997. https://tools.ietf.org/html/rfc2153	IETF	1997
[37] RFC 8200	Internet Protocol, Version 6 (IPv6) Specification	IETF	2017
[38] RFC 2515	Definitions of Managed Objects for ATM Management	IETF	1999
[39] RFC 2516	"A Method for Transmitting PPP Over Ethernet (PPPoE)", IETF Informational Standard, February 1999. Available at "https://tools.ietf.org/html/rfc2516"	IETF	1999
[40] RFC 1661	"The Point-to-Point Protocol (PPP)", IETF Internet Standard, July 1994, Available at "https://tools.ietf.org/html/rfc1661"	IETF	1994
[41] RFC 2661	Layer Two Tunneling Protocol "L2TP"	IETF	1999
[42] RFC 2865	Remote Authentication Dial In User Service (RADIUS)	IETF	2000
[43] RFC 3748	"Extensible Authentication Protocol (EAP)", IETF Proposed Standard, June 2004. Available at "https://tools.ietf.org/html/rfc3748"	IETF	2004
[44] RFC 3772	"Point-to-Point Protocol (PPP) Vendor Protocol", IETF Proposed Standard, May 2004. Available at "https://tools.ietf.org/html/rfc3772"	IETF	2004

[45] RFC 3931	Layer Two Tunneling Protocol - Version 3 (L2TPv3)	IETF	2005
[46] RFC 4282	The Network Access Identifier	IETF	2005
[47] RFC 4861	Neighbor Discovery for IP version 6 (IPv6)	IETF	2007
[48] RFC 4638	Accommodating a Maximum Transit Unit / Maximum Receive Unit (MTU/MRU) Greater Than 1492 in the Point-to-Point Protocol over Ethernet (PPPoE)	IETF	2006
[49] RFC 4187	Extensible Authentication Protocol Method for 3rd Generation Authentication and Key Agreement (EAP-AKA)	IETF	2006
[50] RFC 5458	Improved Extensible Authentication Protocol Method for 3rd Generation Authentication and Key Agreement (EAP-AKA')	IETF	2009
[51] RFC 6691	TCP Options and Maximum Segment Size	IETF	2012
[52] RFC 8174	Ambiguity of Uppercase vs Lowercase in RFC2119 Key Words	IETF	2017
[53] RFC 6957	Duplicate DAD Detection Proxy	IETF	2013
[54] RFC 6221	Lightweight DHCPv6 Relay Agent	IETF	2011
[55] RFC 6788	The Line-Identification Option	IETF	2012
[56] RFC 2868	RADIUS Attributes for Tunnel Protocol Support	IETF	2000
[57] RFC 5515	Layer 2 Tunneling Protocol (L2TP) Access Line Information Attribute Value Pair (AVP) Extensions	IETF	2009
[58] I.363.1	B-ISDN ATM ADAPTATION LAYER SPECIFICATION: TYPE 1 AAL	ITU-T	1996

2.3 Definitions

The following terminology is used throughout this Technical Report.

5G-RG	An RG acting as a 3GPP UE towards the 5GC. **Note:** This corresponds to the term 5G-BRG in [23].
5G VLAN	5G VLAN refers to the VLAN delineated access circuit that is used for NAS CP exchange and transport of all 5WE encapsulated UP traffic between a 5G-RG and an AGF. There is one 5G-VLAN provisioned per 5G-RG. This may also be the access circuit previously used for FN-RG support in migration scenarios. The 5G-RG is either configured with the VID to use for the 5G VLAN, or defaults to using NULL or priority tagged VLAN encapsulation for NAS and 5WE traffic.
5WE Session ID	5WE Session ID is the identifier of the 5WE session corresponding to the 5G-RG's PDU session ID used in the user plane between 5G-RG and AGF.
Access Network (AN)	A network used by a subscriber device to access a service edge, typically IP edge, i.e., BNG, P-GW, 5G core.

Access Gateway function (AGF)	A function connecting wireline ANs to the 5GC. AGF-CP is the control plane while AGF-UP is the user plane of the AGF. **Note:** This corresponds to the term W-AGF in [23].
FN-RG	An RG connecting a home LAN to the WAN, which does not exchange N1 signaling with the 5GC. **Note:** This corresponds to the term FN-BRG in [23].
Hybrid Access	Access that utilizes both wireline access networks and wireless access networks. From the perspective of an RG, 5G-RG or UE. This can either be exclusive or simultaneous access.
N1	Reference point between the 5G-RG and the AMF and between the AGF-CP and AMF in case of FN-RG.
N2	Reference point between W-5GAN and AMF. On the W-5GAN side, the termination point is the AGF-CP.
N3	Reference point between W-5GAN and UPF. On the W-5GAN side, the termination point is the AGF-UP.
PDU Session ID	PDU Session ID is the identifier of each PDU session in the 5G system. It is administered by the 5G-RG.
Wireline 5G Access Network (W-5GAN)	This is a wireline AN that can connect to a 5G core via the AGF. The egress interfaces of a W-5GAN form the border between access and core. The interfaces are N2 for the control plane and N3 for the user plane.
Wireline Access Network	Access network conforming with TR-101/TR-178, that can be for example optical fiber or electrical cable. The egress interface of a wireline access network is the V interface. The wireline access network includes wireline access nodes and optionally some form of aggregation.
Wireless Access Network	Access Network whose physical media or channel is air, e.g., Cellular, techniques, e.g., egress interface of a 4G cellular access network is S1.

2.3.1 Definitions of 3GPP concepts:

The following definitions summarize 3GPP definitions. In case of inconsistency between the text in the following and 3GPP definition (please refer to the referenced documents in section 2.2), the 3GPP definition takes precedence.

5G System (5GS)	A system consisting of 5G Access Network (AN), 5G Core Network and UE.
Network Instance	Information identifying a domain. Used by the UPF for traffic detection and routing (definition from TS 23.501 [26]).
Network Slice	A logical network that provides specific network capabilities and network characteristics (definition from TS 23.501 [26]).
Network Slice Instance	A set of Network Function instances and the required resources (e.g., compute, storage and networking resources) which form a deployed Network Slice (definition from TS 23.501 [26]).
Network Slice Selection Assistance Information (NSSAI)	The NSSAI is a collection of S-NSSAIs (Single NSSAIs). An NSSAI may be a Configured NSSAI, a Requested NSSAI or an Allowed NSSAI. There can be at most eight S-NSSAIs in Allowed and Requested NSSAIs sent in signaling messages between the UE and the Network. The NSSAI is defined in TS 23.501 [26].

Allowed NSSAI	An NSSAI provided by the serving PLMN during e.g., a registration procedure, indicating the S-NSSAI's value that the UE could use in the serving PLMN of the current registration area. The Allowed NSSAI is defined in TS 23.501 [26].
Configured NSSAI	An NSSAI that has been provisioned in the 5G-RG applicable to one or more PLMN (the Configured NSSAI is defined in TS 23.501 [26]).
Requested NSSAI	An NSSAI provided by the UE to the Serving PLMN during registration. The Requested NSSAI is defined in TS 23.501 [26].
Subscribed NSSAI	An NSSAI based on subscriber information, which a UE is subscribed to use in a PLMN. The Subscribed NSSAI is defined in TS 23.501 [26] and the format of S-NSSAI is defined in TS 23.003 [24].
IP and PDU sessions	Where used, the term IP session refers to the BBF concept of an IP session as documented in TR-146 [7]. Where used, the term PDU session refers to the 3GPP concept as defined in TS 23.501 [26]. A PDU session is a temporal association between the UE and a Data Network that provides a PDU connectivity service. As described in TR-146 [7], IP session corresponds to a single protocol (IPv4 or IPv6) whereas a PDU session may provide dual stack support. An IP session may be IPoE based or negotiated by one or more network control protocols over a PPPoE session. Hence there is not necessarily a 1:1 correspondence between them, a PDU session may support two IP sessions; an IPv4 session and an IPv6 session.
Access & Mobility Management Function (AMF)	The AMF is a 5GC-CP function that in particular terminates N1 and N2. It is responsible for mobility and access related functions. It acts as the security anchor point for a given UE. At PDU session establishment, it selects the SMF corresponding to the requested slice and targeted DN, and relays session related messages to this SMF. For detailed specification of AMF refers to 3GPP documents [23] and [27].
Session Management Function (SMF)	The SMF is a 5GC control plane function. For detailed specification of SMF refers to 3GPP documents [23], [26], [27]. Its main functionalities include: • establishing, modifying and releasing sessions • maintaining tunnel(s) between the UPF and access network • UPF control and selection • address allocation • policy control via UPF. • charging data collection and reporting

User Plane Function (UPF)	The UPFs provide user plane functions, its main functionalities are: • PDU session point of interconnection to the Data network • packet routing & forwarding • packet inspection and UP part of Policy rule enforcement • uplink classifier to support routing traffic flows to a data network • branching point to support multi-homed PDU sessions in case of multiple serialized UPFs • QoS handling for UP, e.g., packet filtering, gating, UL/DL rate enforcement, transport level packet marking • Lawful intercept • Traffic Usage Reporting
Policy Control Function (PCF)	The PCF supports a unified policy framework to govern network behavior and provides policy rules to CP function(s) to enforce them. It utilizes subscription information relevant for policy decisions stored in a UDR. The detailed functionalities are described in [28]. The specification for supporting W-5GAN are described in this document and in [23].
User Data Management (UDM)	The UDM provides management of user data information including: • Subscription management • Support of de-concealment of privacy-protected subscription identifier (SUCI) • User Identification Handling (e.g., storage and management of SUPI for each subscriber in the 5G system). The UDM uses subscription information which may be stored in a User Data Repository.
5G-Global Unique Temporary Identifier (5G-GUTI)	The 5G-GUTI provides an unambiguous but temporary identification of the UE that does not reveal the UE or the user's permanent identity in the 5G System (5GS). The 5G-S-TMSI is a shortened form of the 5G-GUTI that only contains the identifier of the AMF within a region of a PLMN (<AMF Set ID><AMF Pointer>) and the temporary identifier of the UE <5G-TMSI>.
Globally Unique AMF Identifier (GUAMI)	The GUAMI uniquely identifies an AMF. It is defined in TS 23.501 [26] and the format of the GUAMI is defined in TS 23.003 [24].

2.4 Abbreviations

This Technical Report uses the following abbreviations:

5WE	5G Wireless Wireline Convergence User Plane Encapsulation
5GC	5G Core Network
5G-RG	Residential gateway with 5G NAS
5QI	5G QoS Identifier
AAA	Authentication, Authorization and Accounting

ACS	Auto-Configuration Server (TR-069)
AGF	Access Gateway Function
AMBR	Aggregate Maximum Bir Rate
AMF	Access and Mobility Management Function
AN	Access Network
API	Application Programming Interface
AS	Access Stratum
ATSSS	Access Traffic Steering, Switching and Splitting
AUSF	Authentication Server Function
BBF	Broadband Forum
BNG	Broadband Network Gateway
BPS	Bytes Per Second
CPE	Customer Premises Equipment
DC	Data Center
DL	Data Link
DHCP	Dynamic Host Configuration Protocol
DN	Data Network
DNN	Domain Name News
EAP	Extensible authentication Protocol
ES	End System
FFS	For Future Study
FMC	Fixed Mobile Convergence
FN-RG	Fixed Residential Gateway without NAS
FSM	Finite State Machine
GBR	Guaranteed Bit Rate
GLI	Global Line Identifier
GTP-U	GPRS Tunneling Protocol User Plane
GW	Gateway
IMSI	International Mobile Subscriber Identity
LCP	Link Control Protocol
LTE	Long Term Evolution
MCC	Mobile Country Code
MFBR	Maximum Flow Bit Rate
MNC	Mobile Network Code
MS-BNG	Multi-Service BNG
NAS	Non-Access Stratum
NAT	Network Address Translation

NEF	Network Exposure Function
NFV	Network Function Virtualization
NFVI	NFV Infrastructure
OAM	Operations, Administration and Management
OSS	Operations Support Systems
PCP	Priority Code Point
PCF	Policy Control Function
PCRF	Policy and Charging Rules Function
PCO	Protocol Configuration Options
PIR	Peak Information Rate
PLMN	Public Land Mobile Network
PSA	Proxy Signaling Agent
PON	Passive Optical Networking
PPP	Point-to-Point Protocol
PPPoE	Point-to-Point Protocol over Ethernet
QFI	QoS Flow Identifier
(R)AN	(Radio) Access Network
RG	Residential Gateway
RG-LWAC	RG-Level Wireline Access Characteristics
RQI	Reflective QoS Indicator
SDN	Software-Defined Networking
SMF	Session Management Function
SM	Session Management
STB	Set Top Box
SUCI	Subscription Concealed Identifier
SUPI	Subscription Permanent Identifier
TCI	Tag Control Information
UE	User Equipment
UDM	Unified Data Management
UDR	User Data Repository
UE	User Equipment
ULI	User Location Information
UPF	User Plane Function
URSP	UE Route Selection Policy
USP	User Services Platform
VSNP	Vendor Specific Network Protocol
VSO	Vendor-Specific Option

3 WWC architecture with AGF

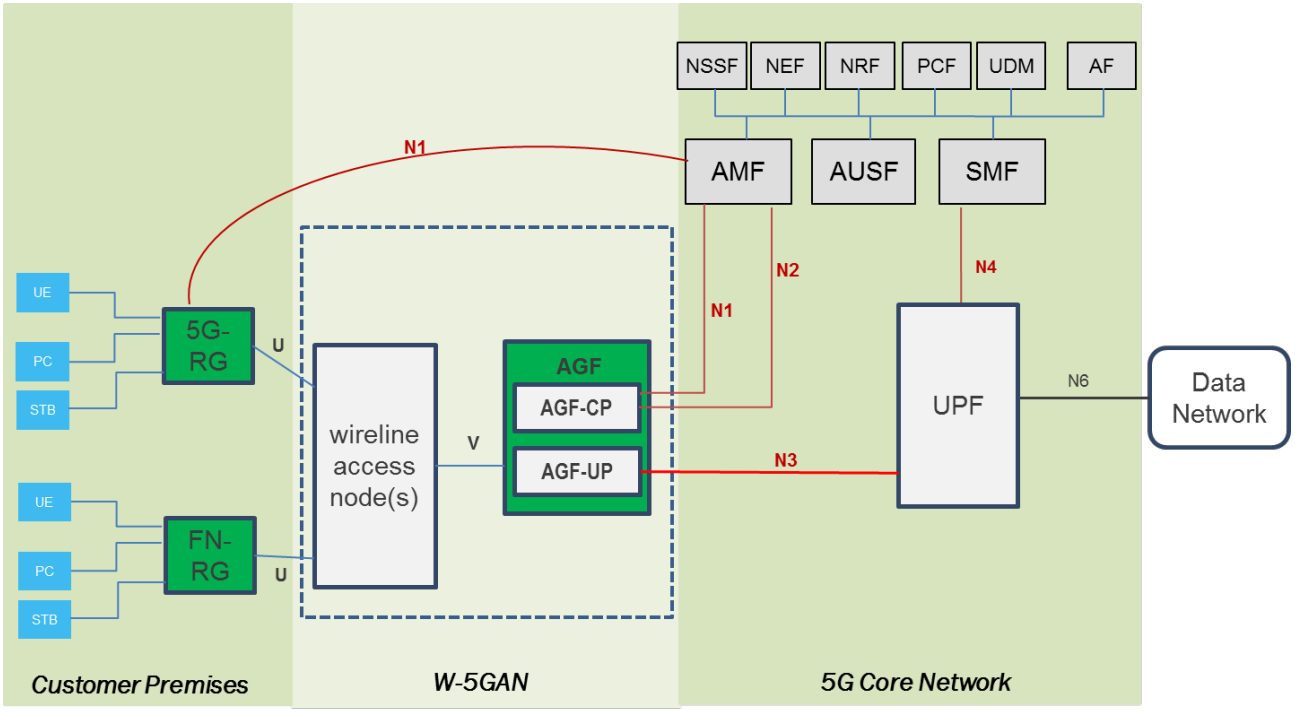


Figure 1: Architectural view of AGF connecting RGs to the 5GC through wireline only access networks.

Figure 1 illustrates a FN-RG and a 5G-RG connected to the 5GC through the Access Gateway Function, AGF. W-5GAN comprises of wireline access nodes and an adaption function for 5G convergence, i.e., the AGF. The AGF may be split into control plane, AGF-CP, and user plane, AGF-UP. The control plane and user plane separation (CUPS) of the AGF is out of scope of this document and is specified in WT-458 [10].

The converged 5G core network is used to deliver functions traditionally offered by the wireline core network as well as potential new 5G services.

The interfaces of the AGF towards the core are N1 (for FN-RG) and N2 for the control plane and N3 for the user plane. They form the border between access and core. These are defined in 3GPP documents referenced in [11], [16], [18] and [19].

In this Figure 1, there is no NG-RAN connecting the 5G-RG, which is only connected via wireline access. However, it is possible that a 5G-RG could use a NG-RAN as well to connect to the 5GC.

The user devices (i.e., UE, PC, and STB) access to the 5G Core Network through the 5G-RG or the FN-RG and W-5GAN.

N1 is supported by 5G-RGs and carried over the W-5GAN. To support an FN-RG, the AGF emulates the N1 interface and generates the Non-Access Stratum (NAS) signaling to the AMF on behalf of the FN-RG.

The interface of the AGF towards the wireline access node is the V reference point as defined in [5].

> **Note:** The FN-RG is always identified by a Line ID/GLI based SUPI and 5G-RG is always identified by an IMSI based SUPI.

4 High-level requirements of an AGF

The AGF supports the following high-level requirements:

[R-FN-1] The AGF MUST support the N1 interface as defined in [11] and [23]

[R-1] The AGF MUST support the N2 interface as defined in [16], [18] and [23].

[R-2] The AGF MUST support the N3 interface as defined in [22] and [23].

[R-3] The AGF MUST support all W-AGF (3GPP terminology for AGF) functionalities described in 23.316 [23] that are not specific to a particular RG type.

[R-FN-2] The AGF MUST support all W-AGF (3GPP terminology for AGF) functionalities described in 23.316 [23] that are specific to the FN-RG and FN-BRG (3GPP terminology explicitly identifying a Broadband FN-RG).

[R-5G-1] The AGF MUST support all W-AGF (3GPP terminology for AGF) functionalities described in 23.316 [23] that are specific to the 5G-RG and 5G-BRG (3GPP terminology explicitly identifying a Broadband 5G-RG).

[R-4] The AGF MUST support all functionalities described in [23] for the W-AGF (3GPP terminology for AGF)

[R-5] The AGF MUST support the V interface as defined in [5]

[R-6] The AGF MUST be able to identify the Line ID as defined in [3] and [4] as signaled by the access network in order to provide location information to the 5GC.

[R-7] The AGF MUST be able to be configured to associate a Line ID source with a subscriber-facing interface. This may be at the granularity of interface/S-tag, interface or platform.

[R-FN-3] The AGF must support Layer 2 Tunneling Protocol (L2TP) from access node concentrator(s) as defined in RFC 2661 [41]

[R-8] The AGF MUST separately administer PPPoE and 5WE session IDs as distinct identifier spaces.

The following requirements are imported by reference from TR-101i2 [3] with BNG replaced with AGF:

[R-FN-4] The AGF MUST support R-190 and R-195

[R-9] The AGF MUST support R-191 through R-194

[R-10] The AGF MUST support R-196 to R-212

Note: Security Functions and DHCP relay are FFS.

The following requirements are imported by reference from TR-177corr 1 [4] with BNG replaced by AGF:

[R-11] The AGF MUST support R-37

The following requirements are imported by reference from TR-187issue 2 [8] with BNG replaced by AGF:

[R-FN-5] The AGF MUST support R-46, R-47, R-49, R-51 to R-53, R-57, R-58

Note: R-56 with the RFC 8200 [37] link model is FFS.

5 NAS and AS Transport and Information Elements

5.1 Theory of operation

There are three classes of control information that are transported between a 5G-RG and an AGF. These are Authentication, Non-Access Stratum (NAS) and Access Stratum (AS).

NAS information is the access independent signaling channel between a 5G-RG and the 5G-system. NAS information is ciphered, opaque to the AGF, implements its own reliability mechanisms, and is simply relayed by the AGF between the 5G-RG and an AMF.

AS information is access specific information communicated from the AGF to the 5G-RG. AS information is not ciphered. There are two classes of AS information communicated to the 5G-RG: subscription information and session information. Subscription information is communicated as part of the 5G-RG registration process and session information is communicated as either part of the PDU session establishment process, at the reactivation of PDU sessions as a result of a service request or as a result of policy control decisions in 5GC.

PPPoE version 1 (RFC 2516 [39]) is used as the underlying transport, carrying PPP (RFC 1661 [40]) and augmented with the BBF vendor specific network protocol (VSNP, RFC 3772 [44]) for NAS and AS encapsulation. PPPoE v1 provides the following capabilities that are utilized in this application.

1) PPPoE PADI can be used to solicit connectivity from any class of service edge (BNG and or AGF) or may be used to explicitly solicit connectivity from an AGF via the use of the 5G service-name tag.

2) LCP is extended with a BBF specified vendor specific information element (VSO) to identify that the purpose of the session is EAP, NAS and AS transport. Rejection of an LCP configuration request that contains the information element indicates that the service platform does not support 5G-RG procedures.

3) LCP provides a signaling channel liveliness check in the form of LCP-ECHO. This is required as in most deployments an AGF will not be directly connected to a 5G-RG.

4) EAP is used for authentication via the exchange of 5G system credentials.

5) The BBF VSNP as the NCP as defined below provides a means of communicating both NAS and AS messages between a 5G-RG and an AGF. The BBF VSNP is initiated by VSNCP procedures [44].

When combined with either 5WE session delineation in the UP, this results in an overall protocol suite as follows between a 5G-RG and an AGF:

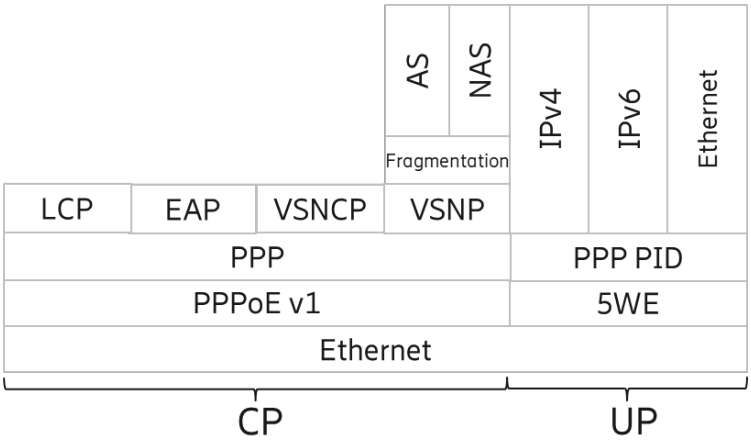


Figure 2: Protocol stacks between a 5G-RG and an AGF

Note that in this design, VSNP is the only NCP opened in the PPPoE v1 session and may only serve one NAS termination.

The encoding of all aspects of NAS and AS communication uses network byte order.

Initiation of CP communication between a 5G-RG and an AGF has each layer brought up in the following sequence with the procedures specific to NAS and AS exchange outlined in the referenced standards and where appropriate augmented by the subsequent sections.

1) PPPoE procedures as documented in RFC 2516 [39] to establish a PPPoE session, and optionally explicitly require connectivity with an AGF.

2) PPP LCP procedures documented in RFC 1661 [40] augmented with the 5G VSO (RFC 2153 [36]) to open the link and to permit 5G procedure support to be negotiated.

3) EAP authentication procedures.

4) VSNCP procedures to open a VSNP channel.

The BBF defined VSNP incorporates a fragmentation layer that offers a single datagram interface to the NAS and AS layer above it. A datagram presented to the fragmentation layer for transmission is termed a service data unit (SDU).

The fragmentation scheme fragments SDUs into zero or more middle fragment messages and an end fragment message. An end fragment contains metadata about the SDU that permits the successful reassembly of the individual fragments back into the SDU to be verified by the receiver. The metadata includes:

1) A CRC-32 of the SDU that is used to validate that all fragments are present and received in the correct order.

2) An SDU length that permits the concatenation of SDUs (via the loss of an end fragment) to be detected and compensated for.

Both NAS and AS SDU exchange is bi-directional. NAS implements reliable transmission. AS is required to also implement a reliability mechanism. This is a simple timeout and application ACK approach.

A NAS or AS SDU is type-length-value (TLV) encoded. The top level TLV identifies whether the SDU is a NAS or AS message. AS TLVs are then broken down into sub-TLVs to distinguish subscription or session

information or application layer acknowledgment. The design permits additional TLVs to be defined in the future.

5.2 PPPoE procedures

The PPPoE transaction is a vehicle an RG uses to discover the service platforms reachable within a L2 broadcast domain and to select one of them to start a PPP session. The first PPPoE message (PADI) allows the RG to also indicate whether it requests a particular service or any service. This is achieved via the "service-name tag" in the PADI, as documented in RFC 2516 [39].

With regards to WWC, the service solicitation sent by the RG over a broadcast domain, and the subsequent service offers (PADO) sent back by the network, can be considered implicit signaling for RG to select the most appropriate service platform as well as to settle the mode of operation of the RG. The final settlement of 5G-RG mode of operation is postponed to a real negotiation that takes place after the PPPoE transaction, in the PPP LCP phase, as documented in section "LCP procedures".

How PPPoE transaction can be triggered depends on the RG. For completeness, hereafter both FN-RG and 5G-RG are considered.

- A FN-RG typically sends a PADI with NULL length service-name tag to trigger the PPPoE transaction. It might also use other service-name tag, for example "DSL" to access the service provided by specific ISPs, but it is assumed to never use the special tag "5G".

- A 5G-RG can trigger the PPPoE transaction in one of the two following ways:

    - Option a: Sending a PADI with NULL length service-name tag: this is used to solicit "any" service platform.
    - Option b: Sending a PADI with "5G" service-name tag: this is used to solicit a 5G service platform that offers access to the 5G system, providing NAS signaling exchange for control plane, and other capabilities.

Option a should be the default way 5G-RG uses to start PPPoE and is better suited for AGF-only (AGF in Adaptive mode only, AGF in both mode) or BNG-only deployments. Notice that in a broadcast domain where both BNG and AGF in adaptive mode are deployed, option a might bring uncertainty on the connection time experienced by the customers, because both service platforms are able to reply to that PADI.

Option b is recommended if the 5G-RG sends the PADI in a broadcast domain where both BNG and AGF in direct mode are deployed. In order to do that, the 5G-RG must be configured on purpose. In this case, according to RFC 2516 [39], BNG is expected to silently discard the PADI, while the AGF will reply with a PADO echoing the service-name tag value: therefore the AGF will be selected by the 5G-RG as serving platform without impact on the connection time experienced by the customers.

The encoding of the 5G service-name tag as per section 5 and appendix A of RFC 2516 [39]:

- Tag type (16-bit): 0x101 (service-name tag)
- Tag length (16-bit): 0x02
- Tag value: '5G' (encoded as ASCII, 0x35, 0x47)

In order to describe how the service selection is carried out by FN-RG and 5G-RG and how 5G-RG identifies its mode of operation, it is necessary to distinguish among the possible behaviors of the service platforms receiving the PADI. These behaviors depend on the network device capabilities and/or on their configuration as shown in Table 1. The following service platform behaviors can be distinguished:

- AGF direct mode only
- AGF adaptive mode only
- AGF both modes
- BNG

Note that when AGF is configured to support both adaptive and direct modes, it will decide how to behave only after the PPP LCP negotiation. No decision is taken at the end of the PPPoE transaction.

Note that a BNG would be expected to provide the same behavior as an AGF that is restricted to adaptive mode only.

RG type	Message sent by RG	Service Platform Behaviors			
		AGF direct mode only	AGF adaptive mode only	AGF both modes	BNG (expected reaction)
FN-RG	PADI with NULL length service-name tag	Silently Discard	Reply with a PADO with no tag	Reply with a PADO with no tag	Reply with a PADO with no tag
5G-RG	PADI with 5G service-name tag	Reply with a PADO with 5G service-name tag	Silently Discard	Reply with a PADO with 5G service-name tag	Silently Discard
5G-RG	PADI with NULL length service-name tag	Silently Discard	Reply with a PADO with no tag	Reply with a PADO with no tag	Reply with a PADO with no tag

Table 1: Different service platform behaviors when replying to PADI.

5.3 LCP procedures

A 5G-RG requests the establishment of 5G control plane connectivity via the inclusion of the BBF defined 5G-RG VSO in the LCP configure-request message. The encoding of the VSO is as per RFC 2153 [36]:

Type = 0

Length = 6 (no values fields are present)

OUI = BBF IEEE administered OUI 0x00256D

Kind = 5 (5G-RG)

An AGF operating in direct mode will respond to the Configure-Request containing 5G-RG VSO with a Configure-Ack, while a BNG or AGF operating in adaptive mode only that does not offer 5G services will respond with a Configure-Reject. A 5G-RG that receives an LCP Configure-Ack will proceed to the EAP-5G procedures as the next step in 5G-RG registration. A 5G-RG that receives a Configure-Reject reverts to FN-RG mode of operation. If reverting to PPPoE operation, then the 5G-RG continues the LCP phase negotiating a non-5G PPP session. If reverting to IPoE operation, the 5G-RG will issue a PADT to clean up the unused PPPoE session attempt.

Note that an AGF operating in direct mode only responds to the Configure-Request not containing 5G-RG VSO with a Configure-Ack, gracefully completing LCP negotiation before terminating the link via an LCP Terminate-Request.

Table 2 describes how the service platform replies based on both its capabilities and configurations and on the service requested by the RGs.

RG type	Message sent by RG	Service Platform Behaviors			
		AGF direct mode only	AGF adaptive mode only	AGF both modes	BNG (expected reaction)
FN-RG	LCP Configure-Request with no VSO	Reply with a Configure-ACK followed by a Terminate-Request	Reply with a Configure-ACK	Reply with a Configure-ACK and operate in adaptive mode	Reply with a Configure-ACK
5G-RG	LCP Configure-Request with 5G-RG VSO	Reply with a Configure-ACK	Reply with a Configure-Reject	Reply with a Configure-ACK and operate in direct mode	Reply with a Configure-Reject
	LCP Configure-Request with no VSO	Reply with a Configure-ACK followed by a Terminate-Request	Reply with a Configure-ACK	Reply with a Configure-ACK and operate in adaptive mode	Reply with a Configure-ACK

Table 2: Different service platform behaviors when replying to LCP Configure-Request.

The AGF or the 5G-RG may terminate CP communication between the 5G-RG and the AGF via closing the LCP NAS and AS channel. Upon completion of these steps the AGF or 5G-RG will issue a PPPoE PADT.

5.4 EAP procedures

The registration procedure with the 5G network takes places before the 5G-RG has any connectivity established. This requires that the NAS Registration request message is carried from 5G-RG to AGF and forwarded to 5GC. EAP-5G defined by 3GPP utilizes the "Expanded" EAP type and the existing 3GPP Vendor-Id (i.e., 10415) registered with IANA under the SMI Private Enterprise Code registry. EAP-5G is used to encapsulate NAS messages before the Access Specific control plane connection is authenticated and established. EAP-5G is specified in TS 24.502 [12].

The usage of EAP and related EAP methods for authentication of the 5G-RG using IMSI or NAI based credential are carried within NAS messages as specified in TS 23.501 [26], TS 33.501 [25] and TR-124 [6].

5.5 VNSCP & VSNP Procedures

NAS and AS are communicated over the Vendor Specific Network Protocol (VSNP) which is part of the PPP protocol suite [44]. The VSNP channel is opened using VSNCP procedures. VSNCP permits the particular protocol encapsulated in VSNP to be negotiated using the PPP negotiation state machine documented in RFC 1661 [40]. VSNP itself has no state machine and is simply an encapsulation. It is entirely dependent on the vendor defined extensions for all aspects of information transfer.

There are no options in the BBF specified VSNP application so the 5G-RG Configure Request that starts the negotiation simply encodes the BBF OUI to identify the protocol used with no additional data. The IEEE

administered BBF OUI is 0x00256D (this has also been registered with IANA). Once VSNCP negotiation has successfully completed, NAS and AS can be communicated over VSNP using the procedures documented in this section.

5.6 VSNP Fragmentation Sub-Layer

Fragmentation sub-layer encoding

The Fragmentation sub-layer is encoded as a TLV. The type field is a 16-bit integer and identifies the message type. The length is a 16-bit unsigned integer that provides the octet count of the following fragment.

There are 2 message types used by the Fragmentation sub-layer:

Type = 0: Middle fragment:

Encoding

Where:

Type is a 16-bit unsigned integer, explicitly set to 0.

Fragment length is 16-bit unsigned integer

Fragment is 'fragment-length' octets of message data

Type = 1: End fragment

Encoding:

Where:

Type is a 16-bit unsigned integer, explicitly set to 1.

Fragment length is a 16-bit unsigned integer

CRC is an unsigned 32-bit value computed as specified in section 9.2.1.2 of ITU-T recommendation I.363.1 [58].

SDU length is a 16-bit unsigned integer

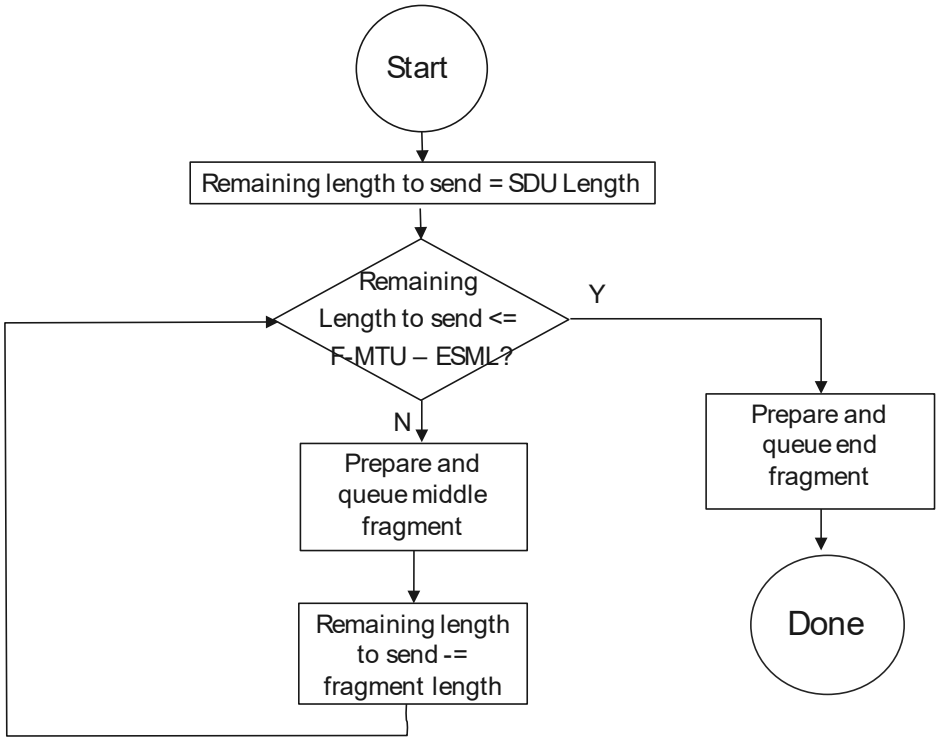
Fragment is 'fragment-length' octets of message data

Reassembly Buffer:

The receiver will implement a reassembly buffer or similar construct to handle reassembly of fragmented messages. The reassembly buffer can be dimensioned in an implementation as the maximum SDU length. The recommended value is 8188 octets as this corresponds to the maximum MTU of the 3GPP RRC layer.

Sender FSM:

The sender finite state machine (FSM) is as follows:



The sender partitions the SDU into one or more fragments and queues them for transmission.

The following variables are used:

SDU length: Is the length of an unfragmented message.

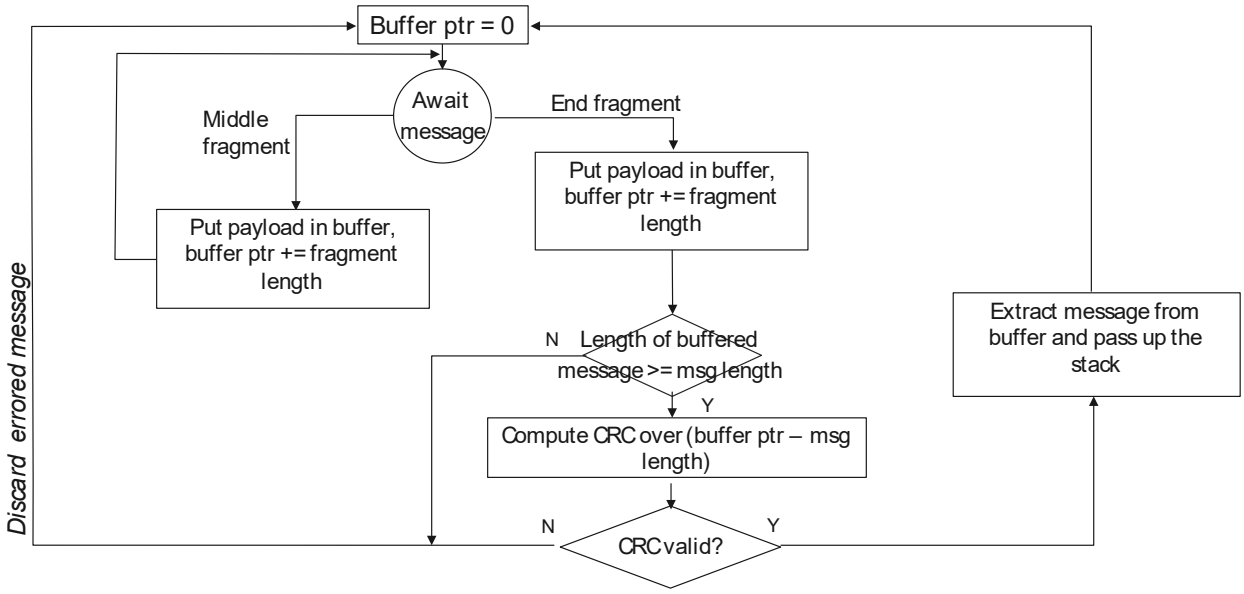
Remaining length to send: is the length remaining net of any fragments already queued for transmission.

F-MTU: is the fragment MTU. For PPPoE with a 1500 bytes Ethernet frame the starting point to determine the MTU is typically 1492 octets. Due to the TLV structure of the fragmentation layer, this reduces the F-MTU value to 1488 octets. Note that this may be extended via procedures documented in RFC 4638 [48].

ESML: End segment metadata length is the length in octets of the end segment meta data (CRC, and SDU length). This is explicitly 6 octets.

Receiver FSM:

The receiver finite state machine is as follows:



The receiver copies message fragments into the reassembly buffer until an end-segment is received. The receiver uses the SDU length encoded in the end segment metadata to determine the start of the message in the reassembly buffer and if at least the number of octets in the SDU length has actually been received. If the received message is too short, the received data discarded. If sufficient data is present It computes the CRC for the message and checks this against the CRC encoded in the end segment metadata. If the CRC is correct, then the message is passed to the higher layers for processing, else the message is discarded.

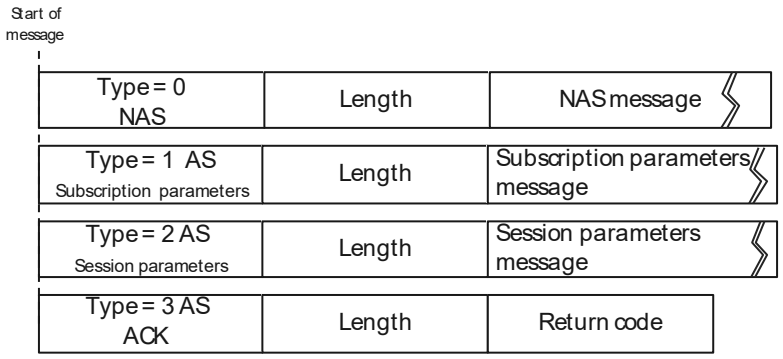
The receiver FSM uses the following variables:

Buffer_ptr: current position of the next octet to be received in the reassembly buffer.

5.7 NAS and AS channel TLV

The communication of NAS and AS messages uses a type-length-value (TLV) encoding. The type field is 16-bits. The length field is a 16-bit unsigned integer and specifies the length of the value field in octets. A message will typically contain only one NAS or one AS TLV. However, under some circumstances (e.g., piggy backing of a NAS IE with an AS PDU session parameters TLV) a message SDU may contain one of each class of TLV.

The TLV structure of a NAS and AS message is as follows:



There are four TLVs defined (NAS, and AS).

NAS TLV:

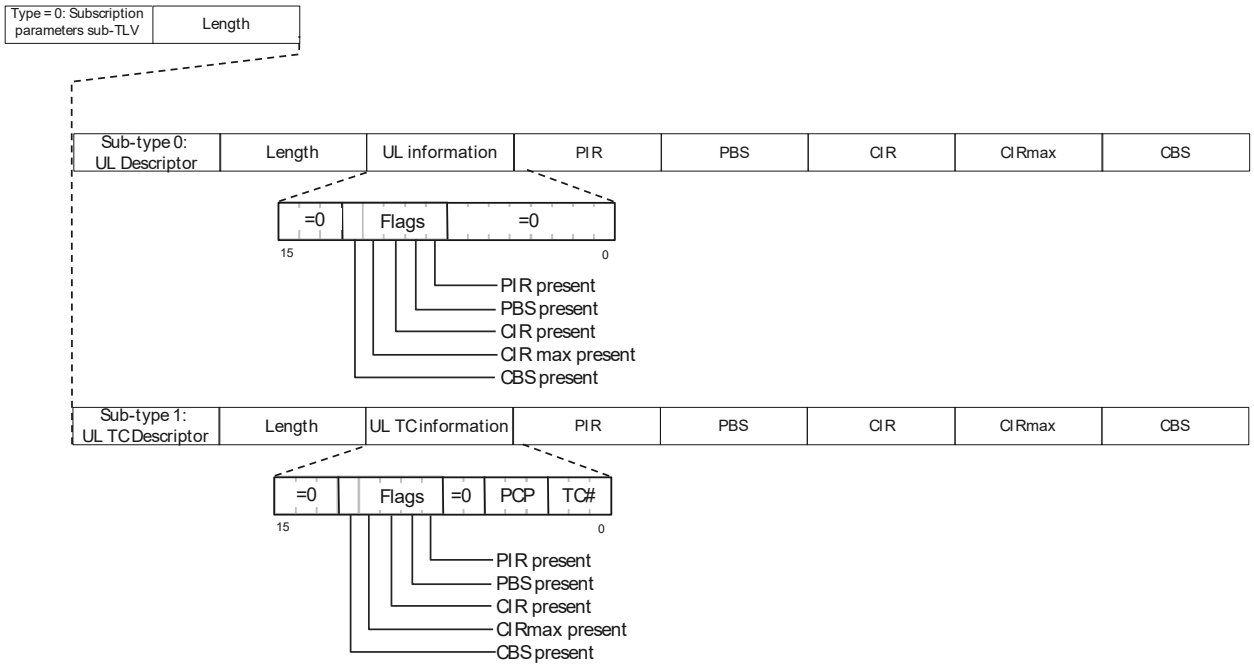
A NAS message is presented to the datagram interface as a ciphered blob. The contents of a NAS message are specified by 3GPP.

AS TLVs:

In messages from the AGF to the 5G-RG the valid AS TLVs are the subscription parameters TLV and the session parameters TLV. In messages from the 5G-RG to the AGF the only valid TLV is the AS ACK TLV.

All information exchanged via AS messages is idempotent.

AS Subscription Parameters TLV: The subscription parameters TLV contains information communicated from the AGF to the 5G-RG at registration time. The subscription parameters TLV is encoded as follows:



The TLV is composed of two sub-TLVs, a single UL descriptor TLV and up to 8 UL traffic class descriptors. Both are variable length depending on what fields are required to describe either the overall upstream characteristics, or the individual traffic class.

The traffic fields are:

CIR	committed information rate
CIRmax	maximum committed information rate
CBS	committed burst size
PIR	peak information rate
PBS	peak burst size

The UL descriptor provides an overall description of the uplink traffic contract to which the resource envelope the sum of the traffic classes has to fit into.

- The sub-type field is 16-bit unsigned integer
- The length field is 16-bit unsigned integer
- The UL information field is 16-bit unsigned integer
    - The flags in the UL information indicate what trailing fields are present
- The PIR and CIR fields are 64-bit unsigned values expressed as bits per second

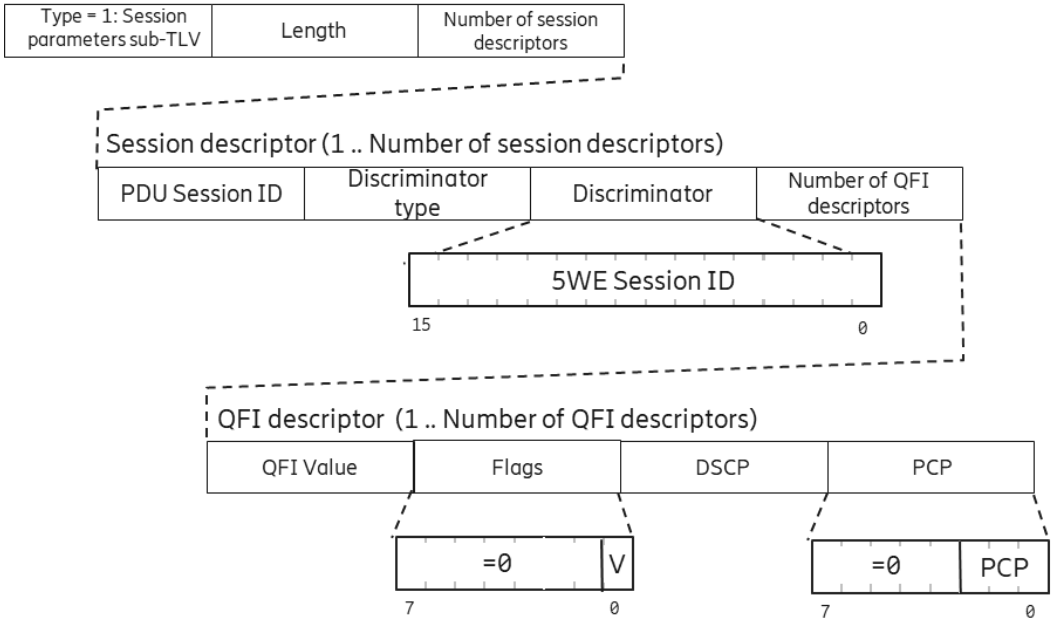
- The CBS and PBS fields are 32-bit unsigned value expressed as the maximum burst size in bytes

The UL TC descriptor provides a description of the uplink traffic class as well as the traffic class number as an identifier and the PCP marking to map the TC to queue, and permit QFI to TC mapping to be performed by a combination of the subscription and session parameters.

- The sub-type field is 16-bit unsigned integer
- The length field is 16-bit unsigned integer
- The UL TC information field is 16-bit unsigned integer
    - The flags in the UL information indicate what trailing fields are present
    - The TC number ranges 0-7.
    - The PCP marking ranges 0-7
- The flags in the UL TC information indicate what trailing fields are present
- The PIR and CIR fields are 64-bit unsigned values expressed as bits per second
- The CBS and PBS fields are 32-bit unsigned value expressed as the maximum burst size in bytes

AS Session Parameters TLV: The session parameters TLV communicates access layer specific information from the AGF to the 5G-RG at the time of PDU session initiation, or when a service request is being fulfilled. A session parameters TLV can contain one or more session records. A session record contains session binding information and one or more QFI mapping records.

The encoding of the session parameters TLV is as follows:



Where:

Number of session descriptors is a 16-bit unsigned value.

A session descriptor is a variable length record which encodes the following:

PDU Session ID: 8-bit unsigned integer

User plane session binding information:

Discriminator type: 8-bit unsigned value. Currently defined values are:

1 for 5WE session ID as session discriminator

Discriminator: 16-bit integer, where the actual encoding depends on the Discriminator type. Where the encodings are:

5WE session ID: The 5WE session ID is used with the VLAN ID assigned to NAS, AS and 5WE delineated PDU sessions as locally configured at both the 5G-RG and the AGF.

Number of QFI descriptors is an 8-bit unsigned value. Number of QFI descriptors indicates the number of QFI descriptors that follow the session binding information. These are the valid QFI values for the PDU session and their corresponding incarnations at the IP and Ethernet layers. The first QFI descriptor is the default QFI for the PDU session.

A QFI descriptor is fixed length of 4 octets and encodes the follows:

QFI value: 8-bit unsigned integer.

Flags: 8-bits, upper 7-bits reserved and must be set to zero. Lower bit ('V') indicates the validity of the following DSCP and PCP fields.

- If the LSB is set to zero, the DSCP and PCP information is not valid, and local configuration should be used. The DSCP and PCP fields must be set to zero.
- If the LSB is set to one, the following DSCP and PCP information should be used for layer 2 and layer 3 marking corresponding to the QFI.

DSCP: 8-bit IP DSCP value that corresponds to QFI value and is used for layer 3 marking.

PCP: 8-bit unsigned integer. The lower 3-bits encode the corresponding 802.1Q [30] PCP marking to use in the Ethernet frame which corresponds to the QFI value and used both for layer 2 marking and TCI for AN scheduling. The upper 5-bits MUST be set to zero.

AS ACK TLV: The AS ACK TLV acts as an application layer acknowledgement. It is a signed 16-bit value with error return codes encoded as negative numbers. The defined return codes are:

0	Message successfully received and understood
-1	Unspecified parsing error

Further values are FFS.

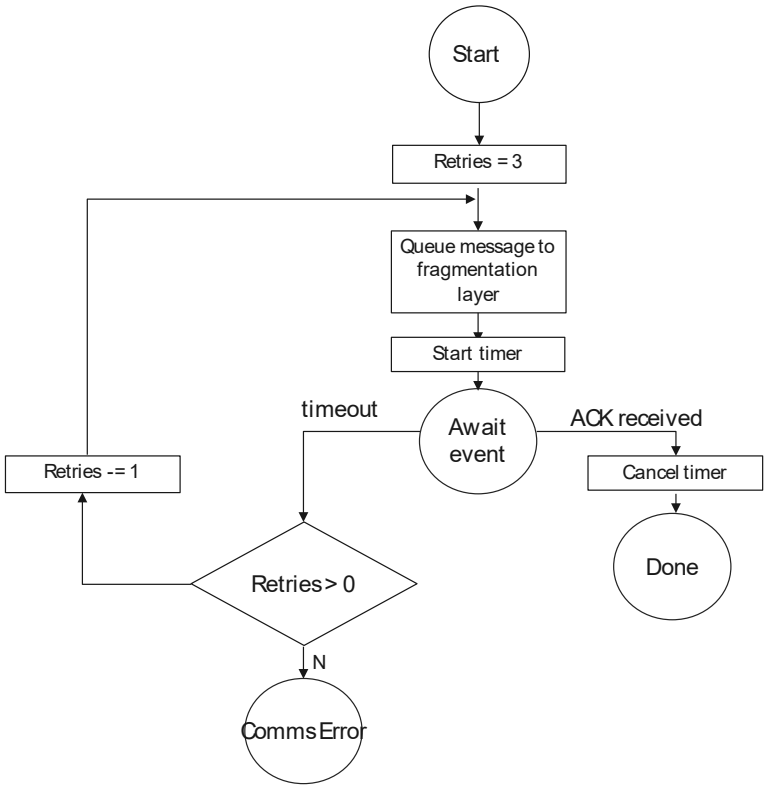
5.8 AS Reliability

AS messages flow from the AGF to the 5G-RG and are acknowledged by the 5G-RG once processed to completion. This includes the parsing and updating of state in the 5G-RG as a consequence of message content. The acknowledgement serves to indicate both successful message receipt, and that the message was either successfully or unsuccessfully understood.

AS messages are idempotent, therefore duplicate detection is not required.

AGF AS FSM:

The AGF FSM is as follows:



When the AGF initiates sending an AS message it initializes a retry counter to 3 retries and starts a timer. The timer value is FFS. If the timer expires before an ACK message is received, the retry counter is decremented, and if not zero, the message is resent.

The AGF will not initiate communication of any additional AS messages while the disposition of the first is unknown.

5G-RG AS message handling

Upon receipt of an AS message, the 5G-RG processes the message to completion and sends an AS ACK message with an appropriate return code to the AGF. The 5G-RG does not originate any AS messages therefore does not require timers, a retry mechanism or any other aspects of reliably delivery.

6 Functional features and requirements

6.1 Authentication/Authorization/identity management

In order to access to 5GC, each subscriber is allocated one 5G Subscription Permanent Identifier (SUPI) for use within the 3GPP system. The SUPI is the permanent identity which identifies the subscriber and it is used only inside the 3GPP system. The privacy for SUPI is defined in TS 33.501 [25] and in TS 23.003 [24]. The SUPI, in respect to the 5G system, is never provided by UE to the network element, but it is confined to the Core network and exchanged between the NF(s) in the core network. The UE in the procedure communicates its Subscription Concealed Identifier (SUCI). The exception is the case of Emergency Services, where the identification of UE, take precedence over the privacy requirements. TR-470 [9] section 7.5 (SUPI/SUCI for FN-RG) provides additional background information about SUPI and SUCI usage for FN-RG.

[R-FN-6] The AGF MUST generate the SUCI as defined in TS 23.003 [24] clause 2.2B, and encode its parts as follows: SUPI-type=2 (Global Line ID); Home Network Identifier=MCC+MNC of the AGF's PLMN (as defined in TR-470 [9] section 7.5); Routing Indicator=0; Protection Scheme ID=0 (NULL scheme); Scheme Output=Global Line ID (as defined in TR-470 [9] section 7.2).

[R-FN-7] The AGF MUST be able to use DHCPv4 option 82 inserted by the AN as specified in [3] as source information for the Global Line ID.

[R-FN-8] The AGF MUST be able to use PPPoE Circuit and Remote ID tags inserted by the AN as specified in [3] as source information for the Global Line ID.

[R-FN-9] The AGF MUST be able to use DHCPv6 option 18 via LDRA functionality in the access node as specified in [4] as source information for the Global Line ID.

[R-FN-10] The AGF MUST be able to use the Line ID Option (LIO) in RS messaging as specified in [4] as source information for the Global Line ID.

[R-FN-11] The AGF MUST be able to use the Circuit ID AVP and/or the Remote ID AVP in the ICRQ message, as specified in RFC 5515 [57] as source information for the Global Line ID.

Requirements related to 5G-RG and N1 support are specified in TR-124 [6].

Hereafter it is explained how the identity of an FN-RG is derived and encoded by the AGF.

SUPI Encoding for FN-RG in AGF

The SUPI generated from the wireline Line ID for a FN-RG is encoded into SUCI using null scheme as defined in TS 23.003 [24].

SUPI: contains PLMN_ID, Line ID source , Line ID as defined in TS 23.003 [24].

An example encoding of SUPI in SUCI for an FN-RG is reported in Figure 3.

Octet	8	7	6	5	4	3	2	1
1	SUPI TYPE (1 - NSI (FN-RG))							
2	MCC Digit 2				MCC Digit 1			
3	MNC Digit 3				MCC Digit 3			
4	MNC Digit 2				MNC Digit 1			
5	Routing Indicator Digit 2				Routing Indicator Digit 1			

6	Routing Indicator Digit 4				Routing Indicator Digit 3
7	spare	spare	spare	spare	Protection Scheme ID (0 for NULL Scheme)
8	Home Network Public Key Identifier (0 for NULL Scheme)				
9 + X	Scheme Output (SUPI in clear text)				

Figure 3: Example encoding of SUPI in SUCI for FN-RG.

Note: The SUPI encoded in the SUCI of the FN-RG may not be the SUPI used in UDM. The SUCI may be defined to be a pseudonym of the SUPI used in the 5GC.

[R-FN-12] The AGF MUST encode the SUCI derived from Line ID for an FN-RG using null protection scheme as defined in TS 23.003 [24].

6.2 Security

6.2.1 N1 (NAS) Security for AGF in adaptive mode

Unlike NAS messages generated by 5G-RG, integrity protection and ciphering for NAS messages generated by the AGF on behalf of FN-RG are not required because the AGF is assumed to be in the same domain as the 5GC. Scenarios where the AGF is in a different domain to the 5GC are FFS.

[R-FN-13] The AGF MUST only use Null Integrity Protection Algorithm for NAS messages generated on behalf of a FN-RG, as defined in TS 33.501 [25].

The AGF will only encode 5G-EA0 for Ciphering Algorithm and 5G-IA0 for Identity protection of the NAS PDUs in the UE Security Capability IE (See TS 33.501 [25])

Procedure for Security mode Command for FN-RG:

Case 1: Null ciphering configured in AMF:

AMF will send the security mode command with 5G-EA0 – AGF will agree and send Security Mode Complete.

Case 2: Null ciphering not configured in AMF:

AMF can send the security mode command with 5G-EA0 – AGF will agree and send Security Mode Complete.

-OR-

AMF can send the security mode command without 5G-EA0 – AGF will send Security Mode Reject. AMF can reinitiate a security mode or stop going forward.

The same is applicable for the Identity protection algorithm.

[R-FN-14] The AGF MUST only use Null Ciphering Algorithm for NAS messages generated on behalf of a FN-RG, as defined in TS 33.501 [25].

6.2.2 N2 Security

The following section describes the encryption requirements for N2 reference point. More details can be found in TS 33.501 [25]).

It is an Operator's decision whether to implement encryption on N2. Encryption on N2 can be implemented on the AGF or can be achieved via an external security gateway.

> **Note:** The AMF already supports negotiation of null cyphering, hence there is no new requirement on AMF to support this model.

For Wireline Access (AGF), an external security gateway (SEG) on the access side can be used to provide IPSec/DTLS based encryption support in case the Operator wants to secure the N2 endpoints.

The SEG is an external device and it is not managed by AGF or 5G Control Plane.

6.2.3 User Plane Data Security (N3)

TS 33.501 [25] Clause 9.3 provides option to use SEG to terminate the IPSec tunnel for N3 Endpoint on the core network side (UPF).

In case of Wireline Access, a SEG can be used to terminate the IPSec tunnel for N3 Endpoint on the AGF side.

6.3 User plane

6.3.1 User plane for 5G-RG

The user plane encoding employed for PDU exchange between an AGF and a 5G-RG will be the IP packet or Ethernet frame appropriate to the PDU session type encapsulated in the '5G WWC Encapsulation'(5WE) [29] and then adapted into TR-101/178 ([3], [5]) Ethernet transport.

The user plane connection is established via the PDU session establishment procedure described in section 8.2.3. This procedure is initiated by the 5G-RG sending PDU Session Establishment request. A PDU Session ID is generated by the 5G-RG. The 5GC informs the AGF of the PDU session ID in the N2 PDU Session Resource Setup Request. Afterwards, the AGF assigns a 5WE session ID and binds it to the PDU session ID. How the AGF administers pools of 5WE session IDs (e.g., per subscriber, per interface, per platform etc.) is up to implementation. This 5WE session ID and PDU session ID binding is communicated to the 5G-RG. The 5G-RG MUST use this 5WE session ID going forward to identify the UP packets of the PDU session.

As shown in Figure 4, the 5WE encapsulation is used to encode the 5WE session ID, QFI/RQI and the encapsulated protocol (IPv4, IPv6 or Ethernet). Note that RQI is optional (RG may decide not to support it or 5GC may decide not to use it). The VLAN used for 5WE encapsulated session traffic is known as the 5G VLAN. The VID to use for the 5G-VLAN is preconfigured on the 5G-RG and will default to the untagged or priority tagged VID.

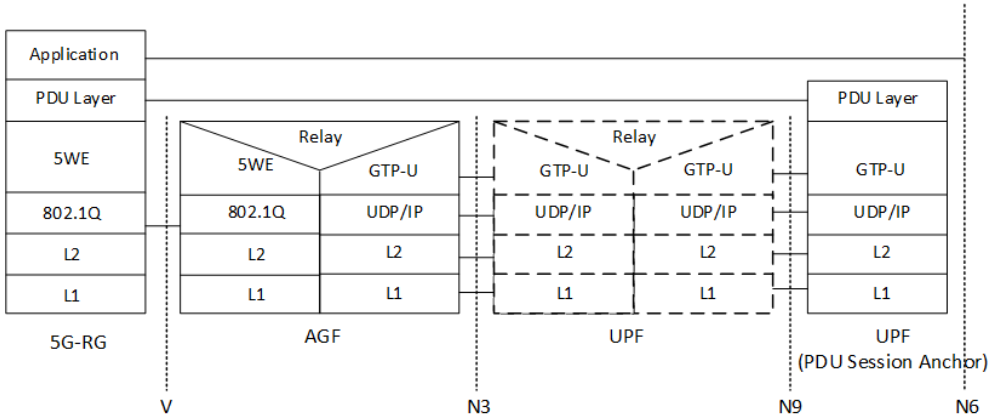


Figure 4: User Plane via AGF for 5G-RG.

The AGF needs to maintain a context per PDU session for each 5G-RG. The following information is maintained by the AGF associated with a PDU Session ID:

- The Line ID associated with the session,
- The PDU session ID assigned by the 5G-RG,
- The 5WE session ID assigned by the AGF,
- The IEEE 802 MAC address of the 5G-RG that terminates the PDU session,
- The VLAN tag control information (TCI) at V interface, as specified in IEEE 802.1Q [30], associated with the access circuit connecting the AGF to the 5G-RG.
- The TEID and UPF's IP address of the N3 interface instance associated with the PDU session.
- The mapping of permissible PDU session QFI values to Ethernet Priority Code Point (PCP) values and/or DSCP values.
- The allowable protocols for the PDU session, e.g.: IPv4 Type, IPv6 Type, or Ethernet Type.

The 5GC informs the AGF of the relationship between QFI and 5G QoS Identifier (5QI) in QoS profile(s) in the N2 PDU Session Resource Setup/Modify/Release Request. By combing with RG-LWAC mapping information for 5QI to 802.1Q PCP and/or DSCP values (identified as 5QI Descriptor). The AGF derives the transport layer priority/traffic class marking (e.g., 802.1Q PCP and/or DSCP value) from the QFI. There are 254 5QIs and only up-to-eight traffic classes, each represented by an 802.1Q PCP value. The mapping between 5QI and 802.1Q PCP is N:1. At a given point of time, a maximum of 64 QoS flows exist in a PDU Session and each uniquely identified by a QFI. Besides mapping the 5QI to 802.1Q PCP value, the AGF may also modify the DSCP value in the PDU layer, in line with the 5QI value.

The QFI and PCP/DSCP mapping is communicated to the 5G-RG by the AGF, for each active QoS flow as part of the PDU session establishment/modification. This allows the 5G-RG to use this direct mapping to derive the PCP/DSCP marking to be used in uplink packets. For a Non-GBR QoS flow, if the Reflective QoS Attribute (RQA, as defined in TS38.300) is associated with a QFI, the 5G-RG can derive the IP-5 tuple filter and the QFI to PCP/DSCP mapping from the received downstream packets. Otherwise, the 5G-RG MUST obtain the mapping rules for uplink packets to QoS flows/QFIs from PDU session establishment/modification related N1 messages.

[R-5G-2] The AGF MUST only support Standardized and Pre-configured 5QI values, i.e., support Non-dynamic 5QI Descriptors as defined in TS38.413 [16] clause 9.3.1.28, without the optional parameters.

[R-5G-3] For each PDU session, the AGF MUST derive and maintain an up-to-date list of QFI and PCP/DSCP mapping pair. For this, the AGF MUST use the 5QI to 802.1Q PCP and/or DSCP mapping information in the RG-LWAC and the QFI-5QI mapping information received from the 5GC, in QoS flow management related messages (N2 PDU session resource setup/modification/release requests).

[R-5G-4] The AGF MUST forward the list of QFI and PCP/DSCP mapping pair to the 5G-RG and update it when any changes are applied. This information is to be encoded in AS session parameter TLVs as defined in section 5.7 (NAS and AS channel TLV).

5WE uses NAS signaling for session establishment, therefore any PPPoE discovery messages sent with a 5WE header version are invalid.

[R-12] The AGF MUST silently discard any PPPoE discovery messages (EtherType 0x8863) received with a 5WE header.

6.3.1.1 Construction of 5WE header by the AGF for downstream information transfer

In the downstream direction, the AGF when relaying a received GTP-U packet from the UPF anchoring a PDU session populates the 5WE header as follows:

Note that where the following requirements in this section differ from [29], the latter is the authoritative source.

[R-5G-5] The 5WE version number MUST be set to 2 indicating this is WWC.

[R-5G-6] The 5WE type field MUST be set to 1.

[R-5G-7] The 5WE QFI field MUST be copied from the GTP encapsulation of the PDU session.

[R-5G-8] The 5WE RQI field MUST be copied from the GTP encapsulation of the PDU session.

[R-5G-9] The AGF MUST map the received N3 encapsulated packet to the local PDU session context, on the basis of the IP address of the UPF at the other end of the N3 interface and the TEID.

[R-5G-10] The 5WE session ID MUST be set to the value in the PDU session context.

[R-5G-11] The 5WE length field MUST be set to the length of the packet data unit received over the N3 interface plus 2 bytes for the protocol ID.

[R-5G-12] The 5WE Protocol ID MUST be set to the protocol encapsulated for the PDU session. The permissible values are drawn from the IANA PPP DLL Protocol Numbers registry and are:

- 0x0021 - IPv4 Packet
- 0x0031 - IEEE 802 Ethernet Frame
- 0x0057 - IPv6 Packet.

In the case of collocated UPF, described in section ‘Combined AGF/UPF’, the internal N3 interface may not implement GTP-U. However, UPF collocation is transparent to the user plane interface between AGF and 5G-RG. This means, from a downstream user plane perspective, the combined AGF/UPF behaves in the same way as an AGF with an external UPF. The requirements above also apply to the combined AGF/UPF, with the understanding that the N3 interface is internal. For example, in the case of an internal N3 interface that does not implement GTP-U encapsulation, the 5WE QFI is set to the QFI that a UPF would have applied on GTP-U packet, based on N4 and/or UPF local configuration.

6.3.1.2 Encapsulation of 5WE encoded packet in Ethernet for downstream transfer

The 5WE encapsulated PDU session packet or frame is then adapted onto the Ethernet transport via the imposition of the Ethernet MAC header and the tag control information from the PDU session context.

[R-5G-13] The AGF MUST be able to encapsulate the 5WE and PDU session packet frame with an IEEE 802 Ethernet MAC header.

[R-5G-14] The SA of the MAC frame MUST be set to the MAC address of the AGF-UP instance relaying the frame in the downstream direction.

[R-5G-15] The DA of the MAC frame MUST be set to the MAC address of the 5G-RG obtained from the PDU session context

[R-5G-16] The VLAN tag control information for the access circuit connecting the AGF and the 5G-RG obtained from the PDU session context MUST be encoded in the Ethernet frame.

[R-5G-17] The Ethernet 802.1Q Priority Code Point value MUST be set to that corresponding to the 5QI value of the QoS flow associated with the QFI value received by the AGF in the GTP-U encapsulation. Note that this may result in packets from multiple QoS flows having the same 802.1Q PCP value.

[R-5G-18] The AGF MUST use the list of QFI and PCP/DSCP mapping pair to map the QFI value as received from the GTP-U encapsulation on N3 interface to a traffic class and the associated traffic conditioning on the 'V' interface.

[R-5G-19] The DSCP Value SHOULD be set to that corresponding to the 5QI associated with the QFI value received by the AGF in the GTP-U encapsulation

6.3.1.3 Construction of N3 header by the AGF for upstream information transfer

The PDU session packet/frame is extracted from received Ethernet frames with 5WE encapsulation and relayed via the N3 interface to the UPF anchor point for the session.

[R-5G-20] The AGF MUST be able to map a received frame to a PDU session context. This is on the basis of 5WE session ID. Note that depending on the AGF implementation, it may be discriminated also by VLAN tag control information, port of arrival and/or SA MAC address.

[R-5G-21] The AGF MUST silently discard any frames received that it is not able to successfully map to a session context.

[R-5G-22] The AGF MUST silently discard any PDUs received that do not have a permissible protocol ID for the PDU session.

[R-5G-23] The AGF MUST be able to construct a GTP-U encapsulated session packet/frame using the payload of the 5WE encapsulated packet/frame and local PDU session context information (UPF IP address, TEID etc.).

[R-5G-24] A GTP-U packet produced by the AGF MUST comply with TS 38.414 [21] and TS 38.415 [22].

[R-5G-25] The AGF MUST be able to perform marking of packets at N3 transport layer, i.e., the UDP/IP encapsulating GTP-U, on a per QoS Flow basis with a transport level packet marking value that is determined based on the 5QI and the ARP priority level of the associated QoS Flow.

[R-5G-26] The AGF MUST be able to map the 802.1Q PCP value of an Ethernet frame received on the 'V' interface to a traffic class policer in the AGF.

6.3.2 User plane for FN-RG

The user plane encoding employed for PDU exchange between an AGF and a FN-RG is based on the traditional wireline protocols documented in TR-101/178 ([3], [5]) (such as IPoverPPP and IPoE). The protocol stack used for user plane is shown in Figure 5.

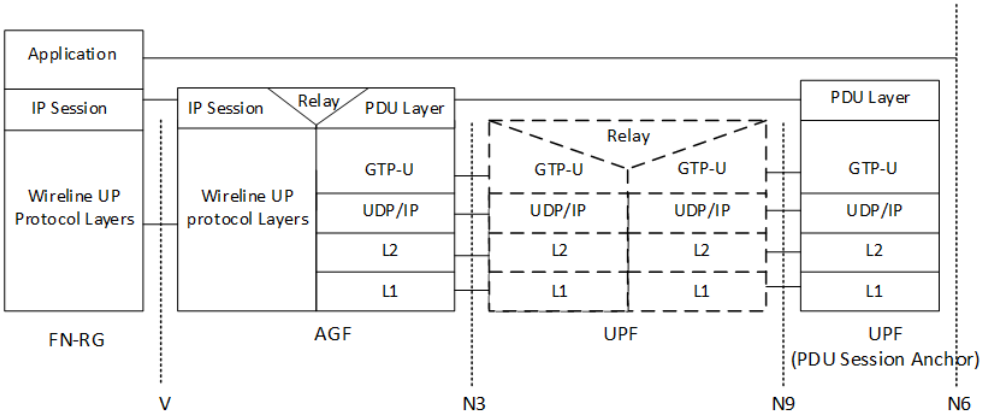


Figure 5: User Plane via AGF for FN-RG.

The user plane connection between FN-RG and AGF follows the IP-session lifecycle management as defined in TR-101/TR-178 and between the AGF and UPF follows the PDU session management as defined

in TS 23.502 [27]. AGF proxies the FN-RG to establish the user plane connection to the 5GC by initiating PDU Session establishment.

6.3.2.1 L2/L3 Interworking

[R-FN-15] An AGF MUST perform a proxy ARP response offering the AGF's FN-RG facing MAC address in response to an ARP transaction resolving the gateway address.

[R-FN-16] The AGF MUST glean an IPoE FN-RG's LLA from transaction that triggers IP session initiation (indirectly from DHCPv4 or directly from DAD, RS or DHCPv6) and encode it in the "suggested interface identifier" IE in the PDU SESSION ESTABLISHMENT REQUEST.

Note: It is assumed that the 5GC will acknowledge the Suggested Interface Identifier IE and echo the IPoE FN-RG's LLA in the PDU SESSION ESTABLISHMENT ACCEPT. This needs to be confirmed with 3GPP and may be updated in a future issue of this document.

[R-FN-17] An AGF MUST use the SMF LLA received in the PDU SESSION ESTABLISHMENT ACCEPT message as the source address for all proxied IPv6 ND responses for IPoE and the network LLA in IPv6CP negotiation for PPPoE.

[R-FN-18] An AGF that does not implement proxy DAD MUST silently discard all IPv6 DAD solicitations from IPoE FN-RGs.

[R-FN-19] An AGF that supports N:1 VLAN model SHOULD maintain a proxy DAD database and be able to appropriately respond to DAD solicitations from IPoE FN-RGs as per RFC 6957 [53].

[R-FN-20] An AGF MUST respond to any IPv6 neighbor solicitation received from an IPoE FN-RG offering its own FN-RG facing MAC address.

[R-FN-21] When configured to support IPoE over N:1 VLAN, an AGF MUST resolve all IPv6 ND destination multicast addresses received from the SMF to the FN-RG unicast MAC address when adapting the ND message to Ethernet. (This is consistent with the spirit of R-44 in TR-177corr1 and necessary for the support of N:1 VLANs).

[R-FN-22] An AGF MUST insert if missing or rewrite if present the Source Link Layer Address option to the FN-RG facing AGF MAC address in any router advertisements received from the SMF when the IP session protocol is IPoE.

Note this requirement is contingent on use of this option in 3GPP specifications. (To be confirmed with 3GPP CT groups.)

6.3.3 Fragmentation and reassembling

Due to possible mismatch between the N3/N9/N6 interfaces MTU and V interface MTU, AGF might need to fragment and/or reassemble.

[R-13] The AGF MUST support IP fragmentation for PDU sessions carrying IPv4 traffic from N3 interface towards the V interface.

[R-14] Combined AGF/UPF MUST support fragmentation for IPv4 PDU sessions carrying IPv4 traffic from N6 or N9 interface towards the V interface.

Note: If the PDU session carries Ethernet traffic, it is FFS how to handle the possible mismatch between the MTU on N3, N6 or N9 interface and the V interface.

[R-15] AGF MUST support ICMPv6 to enable bidirectional IPv6 Path MTU Discovery.

[R-16] AGF MUST support IP fragmentation and reassembly of GTP-U transport on the N3 interface.

[R-17] Combined AGF/UPF MUST support IP fragmentation and reassembly of GTP-U transport on the N9 interface.

Note that in order to avoid AGF fragmenting or reassembling GTP-U PDUs, it is highly recommended that the nodes between UPF and AGF have IPv4 or IPv6 MTUs large enough so that IP fragmentation is not required. Note that in case of a need for fragmentation due to an intermediate tunnel with a limiting MTU, it is recommended to fragment the traffic at the end points. This will reduce the load of fragmenting and reassembling traffic on the Tunnel Endpoints. This optimization can be adopted on N6 interface for the traffic to be tunneled on N3/N9 Interfaces by an UPF towards an AGF.

[R-18] AGF SHOULD be able to be configured to manipulate the TCP Maximum Segment Size of subscriber traffic as documented in RFC 6691 [51]

6.4 Control plane

Control plane traffic is originated by an AGF on behalf of an FN-RG or relayed as NAS PDUs between a 5G-RG and an AMF.

[R-19] The AGF must support Point-to-Point Protocol (PPP) as defined in RFC 1661 [40].

[R-20] The AGF MUST be able to receive the Line ID from the AN.

[R-21] The AGF MUST be able to construct the Global Line ID (GLI) as defined in TR-470 [9] by using the Line ID.

[R-22] The AGF MUST be able to encode the GLI into a User Location Information as define in TS 23.003 [24] and TS 38.413 [16].

[R-23] The AGF MUST be able to construct a Global W-AGF ID to globally identify an AGF node and populate the Global RAN Node ID in N2 messages, as defined in TS 38.413 [16] and TS 29.413 [18].

The AGF determines the class of RG it is supporting on the basis of session initiation traffic received by the AGF from the RG. This is described in detail elsewhere in the document. The formal requirements for detection of class of RG are as follows:

[R-FN-23] The AGF that is configured to support adaptive mode MUST reply to a PADI containing a NULL length service-name tag with a PADO containing a NULL length service-name tag.

[R-5G-27] The AGF that is configured to support direct mode MUST reply to a PADI containing the 5G service name tag with a PADO containing the 5G service-name tag.

[R-24] The AGF that is configured to support only direct mode MUST silently discard any PADIs received with a NULL length service tag.

[R-25] The AGF that is configured to support only adaptive mode MUST silently discard any PADIs received with the 5G service tag.

[R-FN-24] The AGF that is configured to support adaptive mode MUST reply to an LCP Configure-Request not containing the LCP 5G VSO with a Configure-Ack.

[R-5G-28] The AGF that is configured to support direct mode MUST reply to an LCP Configure-Request containing the LCP 5G VSO with a Configure-Ack.

[R-26] The AGF that is configured to support only direct mode MUST reply to an LCP Configure-Request not containing the LCP 5G VSO with a Configure-Ack followed by a Terminate-Request.

[R-27] The AGF that is configured to support only adaptive mode MUST reply to an LCP Configure-Request containing the LCP 5G VSO with an LCP Configure-Reject.

6.4.1 Control plane for 5G-RG

An AGF implements 5G control plane connectivity with a 5G-RG using PPPoE. The actual protocol and procedural aspects as well as the information elements are documented in section 5 (NAS and AS Transport and Information Elements) of this document. How NAS and AS exchange is integrated into procedures for registration management and PDU session management is documented in section 8 (Procedures and call flows). Large NAS packets may be fragmented by the Fragmentation sub-layer as specified in section 5.6 (VSNP Fragmentation Sub-Layer).

The protocol stacks used for control plane are shown in Figure 6 and Figure 7:

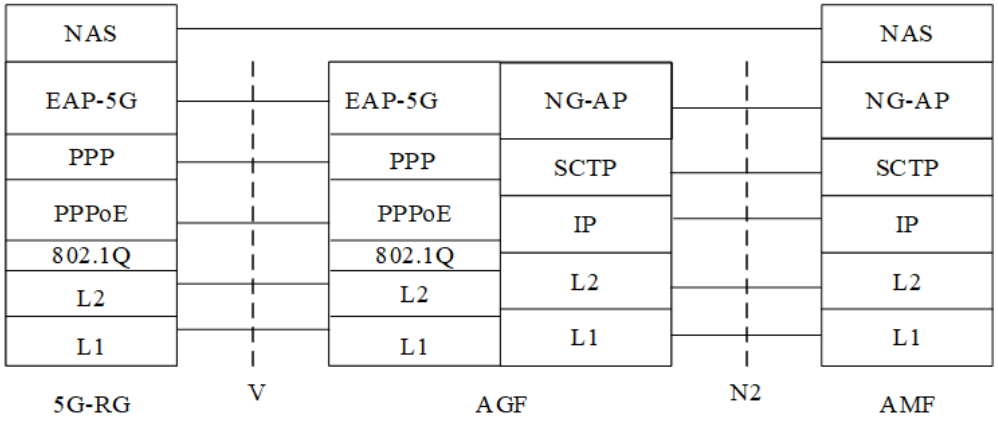


Figure 6: Control Plane between the 5G-RG and the AMF during 3GPP registration

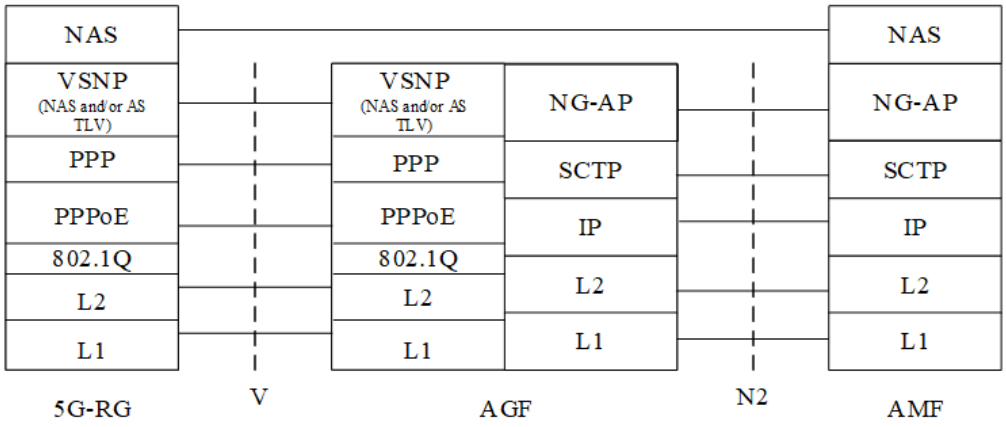


Figure 7: Control Plane between the 5G-RG and the AMF after authentication

The control plane is established by the 5G-RG starting the PPPoE procedure as specified in RFC 2516 [39]. The VLAN used at the U interface is that configured at the 5G-RG for NAS and 5WE exchange, which is called 5G VLAN. The VLAN used at the V interface is that associated with the access circuit connecting the AGF to the 5G-RG. After the PPPoE discovery stage, a PPPoE Session ID will be assigned by the AGF and communicated to the 5G-RG. The 5G-RG will use this Session ID to encapsulate the PPP as specified in RFC 1661 [40] for carrying the NAS message. The following procedures such as LCP, EAP, VSNCP and VSNP are all encapsulated in the PPP with the Protocol field specified based on different stages as per registration procedure:

- 0x0C21 – LCP (Step 5)

- 0xC227 – EAP (Step 6)
- 0x805b – VSNCP (Step 13)
- 0x405b – VSNP (After Step 13)

The AGF needs to maintain a 5G-RG context (N2 specific) for the 5G-RG's control plane. The following information is maintained by the AGF associated with a 5G-RG (identified as a 5G-RG context):

- The Line ID associated with the 5G-RG
- The MAC address of the 5G-RG
- The AN parameters as received from the 5G-RG, e.g., GUAMI, Requested NSSAIs, etc.,
- The Line ID based GLI as constructed by the AGF
- The User Location Information as encoded with GLI by the AGF
- The Global W-AGF ID as constructed by the AGF for globally identifying an AGF
- The VLAN tag control information (TCI) at V interface, as specified in IEEE 802.1Q, associated with the access circuit connecting the AGF to the 5G-RG
- The PPPoE Session ID assigned by the AGF
- The N2 interface identifier for the 5G-RG at the AGF side, i.e., the RAN UE NGAP ID [16] allocated by the AGF.
- The N2 interface identifier for the 5G-RG at the AMF side, i.e., the AMF UE NGAP ID.

[R-5G-29] The AGF MUST be able to use the 5G-RG Line ID to construct the GLI, from the PADI message sent by the 5G-RG initiating the PPP session that transports the NAS, the AS and the EAP-5G messages.

[R-5G-30] The AGF MUST support RFC 2516 [39] PPPoE for the exchange of EAP-5G, NAS and AS information with a 5G-RG [39].

[R-5G-31] The AGF MUST use the 5G-RG MAC address from the 5G-RG context as the L2 5G-RG address when populating the PDU session context.

[R-5G-32] The AGF MUST populate the RG MAC address in the 5G-RG context with the 5G-RG MAC address gleaned from the PADI that initiates the PPPoE CP session.

[R-5G-33] The AGF MUST be able to allocate a PPPoE Session ID to identify the 5G-RG control plane association over the V interface.

[R-5G-34] The AGF MUST include in the LCP Configure Request the Authentication-Protocol Option with value EAP (0xC227).

[R-5G-35] The AGF MUST map the received EAP-5G encapsulated AN parameters (GUAMI, Requested NSSAIs, etc.) to the local 5G-RG context, on the basis of the PPPoE Session ID.

[R-5G-36] The AGF MUST be able to allocate a unique ID for the 5G-RG that will be used in the RAN UE NGAP ID as defined in TS 38.413 [16] to identify the 5G-RG association over the N2 interface.

[R-5G-37] The AGF MUST map the received N2 encapsulated packet to the local 5G-RG context, on the basis of the RAN UE NGAP ID.

[R-5G-38] The AGF MUST forward the received NAS message from the 5G-RG to the AMF on the basis of binding relationship between N2 interface and PPPoE Session ID.

[R-5G-39] The AGF MUST forward the received NAS message from the AMF to the 5G-RG on the basis of binding relationship between PPPoE Session ID and N2 interface.

[R-5G-40] The AGF MUST be able to send the N2 parameters (ULI, Global W-AGF ID, etc.) to the AMF via the N2 interface for the 5G-RG.

[R-5G-41] The AGF MUST support the exchange of NAS UE Registration Management Procedure messages encapsulated within PPP EAP using the expanded EAP type EAP-5G as specified in TS 24.502 [12].

Note that these NAS messages received from the 5G-RG are decapsulated of PPP EAP before sending over N2, and NAS messages received from N2 are sent to the 5G-RG as PPP EAP encapsulated.

[R-5G-42] The AGF MUST support the exchange of NAS UE PDU Session Establishment Procedure and AS Procedure messages encapsulated within PPP VSNP.

Note that these NAS messages received from the 5G-RG are decapsulated of PPP VSNP before sending over N2, and NAS messages received from N2 are sent to the 5G-RG as PPP VSNP encapsulated.

[R-5G-43] The AGF MUST supervise the connectivity of the PPPoE session that transports NAS, AS and EAP-5G using periodic LCP Echo Requests.

[R-5G-44] The AGF MUST consider that the PPPoE session specified in [R-5G-43] has terminated (and the connectivity with the 5G-RG has been lost) upon observing missed replies to 3 consecutive LCP Echo Requests.

[R-5G-45] The periodicity of LCP Echo Requests specified in [R-5G-43] MUST be configurable. It MUST at least include the range from 30 seconds to 3600 seconds.

[R-5G-46] The AGF MUST use a default periodicity of 30 seconds for the LCP Echo Requests specified in [R-5G-45]

Note: An implementation may consider the reception of VSNP encapsulated traffic as the equivalent of a successful LCP Echo Reply and adjust LCP Echo Requests timers/counters accordingly

[R-5G-47] The periodicity of PPP LCP Echo Request liveliness checks MUST be configurable.

[R-5G-48] Upon detecting a fault, either due to a 5G-RG failure or to a loss of connectivity on the PPP link carrying NAS and AS, the AGF MUST start the “AN Release” procedure towards the AMF, as documented in section 8.2.8, and in TS 23.316 [23] clause 7.2.5.2.

6.4.2 Control plane for FN-RG

An AGF proxies 5G control plane connectivity for a FN-RG. The protocol stack used for control plane is shown in Figure 8:

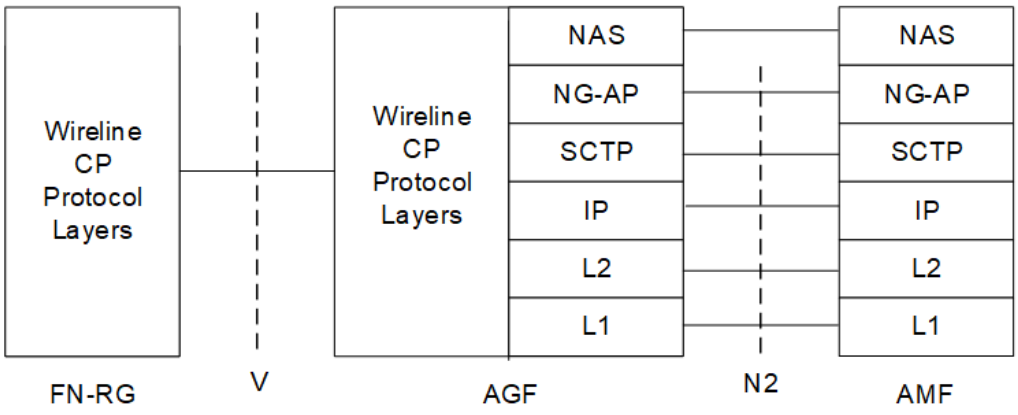


Figure 8: Control Plane between the FN-RG and the AMF

FN-RG initiates the connection with the AGF-CP as described in TR-101. The V interface used for FN-RG connection follows the requirements as defined in TR-101 for BNG. The AGF-CP treats the IP session initiation as a trigger to perform a proxy registration for the FN-RG and establishes the NAS connection with the AMF where the NAS message overlays the N2 interface as defined for 5G-RG.

In addition to the N2 specific 5G-RG context, the AGF needs to maintain N1 specific context for the FN-RG's control plane.

6.5 QoS

6.5.1 RG level QoS Provisioning

TR-101 wireline access networks inherently have end-to-end QoS characteristics that are typically managed on a per-subscriber / household level basis. These QoS characteristics are based on subscription or service tiers and traffic types and flows to and from the subscriber that are specified by an external authority (RADIUS, PCRF, etc.) and/or local configuration. Wireline access QoS, typically represented by the RG as the subscriber, prescribes treatment of traffic to and from the subscriber, including an aggregate downstream and upstream rate.

For 5G WWC similar QoS mechanisms are expected on a per-subscriber or RG-level basis for wireline access to accommodate legacy FN-RG QoS characteristics and QoS characteristics of 5G flows for 5G-RGs. This means the AGF will serve the role of accepting QoS characteristics from the 5GC, applying and enforcing these characteristics, and communicating relevant upstream information to the 5G-RG to enforce. To configure the QoS characteristics of the legacy access networks on the AGF, the AGF receives information from the 5GC known as the RG-Level Wireline Access Characteristics (RG-LWAC). As noted in TS 23.316 [23], these parameters are transparent to the 5GC; it neither interprets nor acts on these parameters, thereby preserving existing 3GPP behavior. The RG-LWAC thus serves as means to map 5G QoS management to a wireline access model.

RG-Level Wireline Access 5G QoS Characteristics

In a PDU session, the QoS flow is used for QoS differentiation in the AN. Each 5G QoS flow has a QoS class identity (5QI) that reflects its traffic forwarding treatment as defined in clause 5.7.2.1 in TS23.501 [26], albeit the AGF will only support standardized and pre-configured (non-standardized) 5G QoS characteristics. The AGF will adapt the 3GPP QoS concept to wireline QoS mechanism. This is done by mapping the 5G QoS Characteristics as defined in TS23.501 clause 5.7.3 [26] to wireline traffic classes and shaping/policing characteristics (e.g., CIR, PIR, etc.). This is achieved using the information encoded in the RG-Level Wireline Access Characteristics (RG-LWAC) data structure possibly augmented with local configuration. The RG-LWAC is provisioned at the UDR, communicated to the AGF during Registration time, and can be updated by the operator anytime.

[R-28] The AGF MUST be able to be locally configured with up to 8 default RG facing traffic class descriptors.

[R-29] The AGF MUST be able to be locally configured with default 5QI to DSCP/PCP mappings.

[R-30] The AGF MUST be able to be locally configured with default PCP to traffic class mappings.

[R-31] The AGF MUST override local configuration of traffic class and mappings on a per subscriber basis with information received in the RG-LWAC data structure.

[R-32] The RG-LWAC MUST contain only Standardized and Pre-configured 5QI values, i.e., support Non-dynamic 5QI Descriptors as defined in TS38.413 [16] clause 9.3.1.28, without the optional parameters.

The RG-LWAC provides the relationship between each 5QI value the operator intends to use for the RG and an 802.1Q PCP and/or a DSCP value. The 802.1Q PCP value represents one of up-to-8 traffic classes that the wireline AN support (e.g., based on its configuration) for the given RG. The 5QI to PCP/DSCP mapping

in RG-LWAC, or local configuration, is used in combination with the 5QI-QFI mapping information as received per PDU session basis.

Besides the 5QI to PCP/DSCP mapping, the RG-LWAC may contain further information applicable for each wireline traffic characteristics for traffic class specific bandwidth limits, shaping and policing configuration. These may supersede or augment local configuration, or the RG-LWAC may be empty and the parameters default to local configuration.

The following tables specify parameters that may be returned in the RG-LWAC. They are defined such that no one parameter is mandatory to allow flexibility of configuring the RG interface from a combination of local AGF configuration combined with parameters sourced from the UDM in these constructs. It also offers flexibility for varying AGF vendor implementations. In the event of a conflict, RG-LWAC configuration SHOULD take precedence over local AGF configuration. This implies the RG-LWAC “blob” is not a fixed-sized construct and can be variable in size to only provide those needed parameters from the AMF.

The following table defines UE (RG) Level QoS characteristics that allow for shaping or policing. All parameters are optional. Note that this is a framework that should not necessarily prevent additional and/or vendor-specific parameters.

Feature	Parameter	Description
DL Descriptor		UE-Level downstream shaper applied on the AGF
	Shaping-Rate	QoS Peak Information Rate (PIR) in BPS
	Shaping-Rate-Burst	Peak Burst Size in bytes
	Guaranteed-Rate	Maximum committed burst rate (CIRmax) in BPS
	Guaranteed-Rate-Burst	Committed Burst Size (CBS) in bytes
	TC-Queue-Profile	Profile specifying explicitly configured bandwidth and scheduling characteristics for up to 8 traffic classes to satisfy supported QFIs. This references the name of a profile/template configured on the AGF that simplifies UDM-sourced configuration. Per TC configuration in the table that follows may be used to prescribe per TC configuration in lieu of this attribute
	Shaping-Profile	Profile specifying Shaping-Rate, Shaping-Rate-Burst, Guaranteed-Rate, Guaranteed-Rate-Burst and TC-Queue-Profile. This references the name of a profile/template configured on the AGF that simplifies UDM-sourced configuration by allowing a single parameter to reference AGF local configuration that fully configures RG-level DL QoS characteristics.
UL Descriptor		UE-Level upstream shaper communicated to the RG by the AGF during AS procedures.
	Shaping-Rate	QoS peak information rate (PIR) in BPS
	Shaping-Rate-Burst	Peak Burst Size in bytes
	Guaranteed-Rate	Maximum committed burst rate (CIRmax) in BPS
	Guaranteed-Rate-Burst	Committed Burst Size in bytes
UL Policing		UE-Level upstream policer applied on the AGF

Feature	Parameter	Description
Descriptor	Bandwidth-Limit	Rate limit bandwidth in BPS
	Burst-Size-Limit	Burst size limit in bytes
	Policer-Template	Template specifying policer attributes, including rate limit value(s), action when rate limit is exceeded, etc. This references the name of a policer template configured on the AGF that simplifies UDM-sourced configuration by allowing a single parameter to reference AGF local configuration that fully configures RG-level UL QoS characteristics.

The following table defines per Traffic Class QoS characteristics that define up to 8 traffic classes on which QFIs are mapped. Only those traffic classes that are used or require configuration are specified. All parameters are optional. Note that this is a framework that should not necessarily prevent additional and/or vendor-specific parameters.

Feature	Parameter	Description
DL TC Descriptor		Per-Traffic Class QoS Configuration
	TC-Queue-Name	Name of the queue representing this Traffic Class. Up to 8 entries are allowed, where this attribute serves as the key
	TC-Shaping-Rate	QoS peak information rate (PIR) in BPS
	TC-Shaping-Rate-Burst	PBS in bytes
	TC-Guaranteed-Rate	Maximum committed burst rate (CIRmax) in BPS
UL TC Descriptor		Per-Traffic Class QoS Configuration communicated to the RG by the AGF during AS procedures.
	TC-Queue-Name	Name of the queue representing this Traffic Class. Up to 8 entries are allowed, where this attribute serves the key
	TC-Shaping-Rate	QoS peak information rate (PIR) in BPS
	TC-Shaping-Rate-Burst	PBS in bytes
	TC-Guaranteed-Rate	Maximum committed burst rate (CIRmax) in BPS
DL TC Policing Descriptor		Per-Traffic Class Downstream policer applied on the AGF. This is optional but may be used in lieu of or in conjunction with DL TC Shaper feature
	TC-Name	Traffic Class name
	TC-Policer-Name	Name of the policer corresponding to this Traffic Class
	TC-Bandwidth-Limit	Rate limit bandwidth in BPS
	TC-Burst-Size-Limit	Burst size limit in bytes

Feature	Parameter	Description
	Aggregate-Policer-Template	Template specifying policer attributes, including rate limit value(s), action when rate limit is exceeded, etc. for each Traffic Class. This references the name of the policer template configured on the AGF that simplifies UDM-sourced configuration by allowing a single parameter to reference AGF local configuration. This may be used in lieu of configuring per TC policer configuration attributes.
UL TC Policing Descriptor		Per-Traffic Class Upstream policer communicated to the RG by the AGF during AS procedures. This is a placeholder and FFS with respect to the RG.
	TC- Name	Traffic Class name
	TC-Policer-Name	Name of the policer corresponding to this Traffic Class
	TC-Bandwidth-Limit	Rate limit bandwidth in BPS
	TC-Burst-Size-Limit	Burst size limit in bytes

The mapping of 5G QFI to Traffic class is achieved by the mapping of QFI to 5QI provided with the PDU session parameters, and then the 5QI is mapped to traffic class using a combination of local configuration and information in the RG-LWAC data structure. The mapping may be sourced from local AGF configuration as it is anticipated to be common among a class of subscribers, where the number of different subscriber classes, and thus different mappings, is expected to be small. Like other parameters described above, it is conceivable to reference an AGF-local 5G QFI to Traffic Class mapping as a profile or template reference in the RG-LWAC.

The following requirements apply:

[R-33] The AGF MUST support applying and enforcing downstream QoS configuration received from the AMF in the RG-LWAC as part of the RG registration process or in the Subscriber Data Update Notification procedure. This includes RG node level and per Traffic-Class configuration as described in the above tables.

[R-34] The AGF SHOULD support applying and enforcing downstream RG-LWAC QoS configuration received from the AMF along with local AGF RG QoS configuration. The AMF-sourced RG-LWAC QoS configuration should override or supplement local AGF configuration.

[R-35] The AGF SHOULD support applying and enforcing downstream RG-LWAC QoS configuration sourced from local AGF Configuration in absence of receiving downstream RG-LWAC QoS configuration from the AMF.

[R-36] The AGF MUST support applying and enforcing upstream QoS configuration received from the AMF in the RG-LWAC. This includes RG node level and per Traffic-Class configuration as described in the above tables.

[R-37] The AGF SHOULD support applying and enforcing upstream RG-LWAC QoS configuration received from the AMF along with local AGF RG QoS configuration. The AMF-sourced RG-LWAC QoS configuration should override or supplement local AGF configuration.

[R-38] The AGF SHOULD support applying and enforcing upstream RG-LWAC QoS configuration sourced from local AGF Configuration in absence of receiving upstream RG-LWAC QoS configuration from the AMF.

[R-5G-49] The AGF MAY support local AGF configuration of upstream RG-Level QoS configuration that can be communicated to the 5G-RG during AS procedures. This may be used in absence of receiving upstream configuration in the RG-LWAC from the AMF during RG procedures.

[R-5G-50] The AGF MUST support communicating upstream RG-LWAC QoS configuration received from the AMF to the 5G-RG using AS procedures as part of RG registration.

[R-5G-51] The AGF MAY support communicating to 5G-RG upstream QoS configuration based on a combination of RG-LWAC QoS configuration from the AMF and local AGF RG QoS configuration, where AMF-sourced RG-LWAC QoS configuration overrides or supplements local AGF configuration, using AS procedures.

PDU Session Level QoS Characteristics

TS 23.316 [23] specifies that each PDU Session of a 5G-RG or FN-RG may be configured with a Session-AMBR that limits the aggregate bandwidth for all Non-GBR QoS Flows for the Session. This is retrieved from the UDM via the SMF during Session Initiation and signaled to the UPF over N4. These QoS characteristics are enforced on the UPF. For a collocated AGF and UPF, the PDU session appears as an additional scheduling layer in the QoS hierarchy. Session-AMBR is only enforced at the 5G-RG and UPF.

FN-RGs do not support GBR functionality as defined by 3GPP, i.e., cannot enforce GBR or MFBR in the upstream direction. Therefore for FN-RG, only GBR QoS flows including only downlink traffic filters can be enforced; this is enforced in the same way in AGF as for 5G-RG. **Note:** For upstream direction, GBR-like behavior may be achieved using FN-RG configuration via ACS. However, this is static behavior and not controlled by the 5GC.

During PDU Session Initiation or PDU session modification, for a GBR QoS flow, the AGF will receive GBR QoS Flow Information. The information element contains MFBR for UL, MFBR for DL, GFBR for UL and GFBR for DL as mandatory, and Notification control, maximum downlink packet loss rate, maximum upstream packet loss rate as optional. The GBR QoS flows are subject to Call Admission Control (CAC) by the AGF based on RG-LWAC (for example, GFBR/MFBR for UL is subject to UL Policing Descriptor and GFBR/MFBR for DL is subject to DL Descriptor), while non-GBR QoS flows are not.

[R-5G-52] For GBR QoS flows, the AGF MUST support GBR QoS Flow Information shown as mandatory as defined in TS38.413 [16] clause 9.3.1.10.

[R-5G-53] The AGF MUST store the GFBR and MFBR value for each GBR QoS flow, as received in N2 PDU Session Resource Setup/Modification Request, for the QFI.

[R-5G-54] When receiving a request for establishing a GBR QoS flow, the AGF MUST exercise admission control

- The AGF MUST then determine the TC that the newly requested GBR QoS flow must be mapped to, based on its 5QI value
- The AGF MUST then ensure that:
  (a) the sum of DL GFBR values of the previously established GBR QoS flows mapped to that TC, plus the DL GFBR of the actually requested QoS flow do not exceed the available CIR capacity belonging to the TC, as defined in the RG-LWAC.
  (b) the sum of UL GFBR values of the previously established GBR QoS flows mapped to that TC, plus the UL GFBR of the actually requested QoS flow do not exceed the available CIR capacity belonging to the TC, as defined in the RG-LWAC.
- If either the sum of DL or UL GFBR would exceed the PIR value, the AGF MUST execute pre-emption procedure based on the Allocation and Retention Priority parameter of each GBR flow, as defined in TS38.413 [16], clause 8.2.1.2. The AGF MUST release the pre-empted QoS flow(s).

[R-5G-55] The AGF SHOULD police the upstream TC for GBR QFIs to the sum of the resource commitments for that TC (which will be less than or equal to the CIR/EIR for the TC).

[R-5G-56] The AGF MUST use the combination of the TC descriptor, the QFI to 5QI to TC mapping and the received per packet IP precedence information as an input into queue management

[R-FN-25] The AGF SHOULD support GBR QoS flows for FN-RG, if the QoS flow includes only DL traffic filters. In this case, functionality equivalent to [R-5G-52], [R-5G-53] and [R-5G-54] is to be supported

Network Access Model

Applying RG-level 5G QoS characteristics implies the RG is represented as an interface on the AGF on which these QoS characteristics are enforced. This is more natural for a customer (1:1) VLAN but requires means to uniquely identify subscribers (RGs) on an N:1 VLAN. RG type specific considerations follow:

5G-RG: This consists of a PPPoE control session, used for NAS and AS procedures and session liveness detection, and one or more PDU sessions, where the combination of the PPPoE control session and PDU sessions are subject to the RG-level QoS characteristics.

FN-RG: An L3 RG is assumed with a single PDU session (multiple PDU sessions and support for bridged RGs is FFS). It typically consists of a single access protocol session supporting either mono-stack or dual-stack. For the service (N:1) VLAN access model (i.e., separate VLANs to the RG for data, voice, IPTV, etc.), separate RG-LWAC may be required as representing all VLAN sessions as a single interface grouping may not be feasible in all cases and is FFS.

For a collocated AGF and UPF, the SMF configures each PDU session with a session-AMBR that limits the aggregate bandwidth for Non-GBR QoS Flows for that session. This is retrieved from the UDM via SMF during session Initiation and signaled to the combined AGF + UPF over N4. This means each PDU session may be represented by its own interface to enforce PDU session level QoS characteristics and support accounting or usage-based monitoring requirements. These PDU sessions are, in turn, subject to RG-level QoS characteristics applied by the AGF during RG Registration over N2 that precedes PDU session Initiation.

QoS Representation on AGF

Multiple QoS models should be assumed, influenced by provider network topologies and QoS requirements for their network. Service providers with a traditional BNG migrating to WWC using 5GC may have a heterogeneous mix of 5G-RGs and FN-RGs and may potentially want to converge on a common QoS model for ease of migration and management of the subscribers.

A common wireline network technique used by providers represent the subscriber RG as an interface on which a shaper is applied with traffic classes represented as queues with configured attributes to honor the QoS requirements commensurate with a subscription plan, service tier, or contracted arrangement with a third-party access provider. Nevertheless, the approach should allow for a policer to be used in lieu of or in combination with a shaper. In the upstream direction a policer is typically used.

A provider typically has a relatively small set of subscription plans or service tiers that can be realized from a combination of local configuration and external authority, where external authority can supplement, override or fully source the QoS characteristics for the subscriber. Means to source the information from external authority can be in the form of individual parameters or references to locally configured templates, profiles or containers, each configured with the required QoS characteristics to meet the service plan. A similar technique should be supported on the AGF to avoid having to source all RG-level configuration from UDM, which, as features and use cases continue to be identified, will only expand over time. Thus, means to combine and reconcile AMF-sourced RG-LWAC with AGF-local configuration maximizes flexibility while avoiding redundant and excessive operator configuration of UDM under scale.

Finally, AGF vendor differences in representing and applying RG-LWAC QoS characteristics is to be expected, which means either “converting” RG-LWAC QoS characteristics to align with the AGF (-U) QoS implementation or providing flexibility to source vendor specific attributes. Referencing the name of a template, profile or container configured on the AGF that specifies QoS configuration and other supporting configuration suitable for the vendor’s implementation is an option to help accommodate such differences. Vendor differentiation and/or operational practice may also require AGF local implementation that is used in conjunction with or in lieu of RG-LWAC information. This technique should prove useful for providers that are already accustomed to configuring common profiles/templates assigned to groups or classes of subscribers for conventional, wireline broadband access that may be supplemented or overridden on a per-subscriber basis from external authority.

6.6 AGF functions for core network signaling

[R-39] The AGF MUST support the same functions for control plane signaling over the N2 interface as defined in TS 23.501 [26] and TS 38.410, 412,413 ([14], [15], [16]). In these reference documents, NG-RAN is to be replaced by AGF.

Note: The TS 29.413 [18] defines how to apply the NGAP protocol (TS 38.413 [16]) for non-3GPP access.

A summary is provided here about the relevant functions, procedures and protocol aspects defined in the above specifications and how they are applicable for AGF. In any case of conflict, the referenced 3GPP R16 specifications have precedence.

- The AGF must support functions to discover, connect and maintain reliable and redundant connections to multiple sets of AMFs, serving one or more network slices.
    a. The AGF must be able to derive and maintain a list of AMFs, to which it must maintain connections over N2 interface. At least one of the below options must be supported:
        i. DNS based discovery as defined in TS 29.303 [17] , clause 7.2 and Annex F.
        ii. Configuration knowledge of AMFs.
    b. AGF must support IP and transport layer requirements for N2 interface, as defined in TS 38.412 [15].
        i. AGF should support multiple SCTP associations (TNLA) towards an AMF and add new ones as requested by AMF. The AGF must request adding additional endpoints using the “RAN configuration update procedure” (see below).
        ii. The AGF must support NGAP UE-TNLA-binding as described in TS 23.501 clause 5.21 [26].
- The AGF must support the following major functions as listed in clause 5 of TS 38.410 [14], with the corresponding procedures defined in clause 8, and N2 messages defined in clause 9.2 of TS 38.413 [16] – as detailed below:
    a. Non-UE-associated services
        i. NG Interface Management functions (TS 38.413 [16] clause 8.7 and 9.2.6) that allows resetting the N2 connection, handling different implementation versions and protocol errors.
        ii. AMF Management function to support AMF planned removal (TS23.501 [26], clause 5.21.2.2 and TS38.413 [16] clause 8.7.6.2) and AMF auto-recovery (TS23.501 [26], clause 5.21.2.3),
        iii. Multiple TNL Associations Support function, supported via AMF and RAN configuration update procedure (TS38.413 [16], clause 9.2.6.4-9) to add/remove SCTP end point on AGF and AMF side and load balance the UE associated signaling across these associations.
        iv. AMF Load Balancing function (TS 38.413 [16] AMF relative capacity in clause 8.7.1 and 8.7.3 and 9.2.6.2/9.2.6.7) to support the indication by the AMF of its relative capacity to the AGF in order to achieve load-balanced AMFs within the pool area.
    b. UE-associated services
        i. NAS Node (i.e., AMF) Selection function (TS 23.501 [26] clause 6.3.5 and 5.15.5.2), to ensure that the AMF supports the requested network slices. For the selection, the AGF must take the AMF configuration and status information into account.
        ii. AMF Re-allocation function (TS 38.413 [16] clause 8.6.5 and 9.2.5.5), to allow that the RG gets served by a different AMF than the one that initially received the registration request.

iii. NAS Transport function (TS 38.413 [16] clause 8.6 and 9.2.5), which supports transport and reroute of NAS messages between 5G-RG and AMF, or AGF-adaptive mode for FN-RG and AGF, respectively.

iv. UE Context Management function (TS 38.413 [16] clause 8.3 and 9.2.2), which enabled the AMF to establish, modify and release UE context in the AMF and the AGF for individual RG related signaling.

Note: RRC state notifications are N/A for AGF.

v. PDU Session Management function (TS 38.413 [16] clause 8.2 and 9.2.1) for establishing, modifying and releasing the involved PDU session related AGF/W-5GAN resources for user data transport once a UE context is available in the NG-RAN node.

vi. Trace function (TS 38.413 [16] clause 8.11 and 9.2.10) to control trace sessions in AGF.

Note: the other functions in clause 5 of TS38.410 [14], Paging, Mobility Management, Warning Message Transmission, Configuration Transfer, Location Reporting, UE Radio Capability Management, Report of Secondary RAT data volumes and RIM Information Transfer functions are not applicable for AGF.

6.7 N2 connections

The AGF needs to fulfil the following requirements about N2 interface:

[R-40] The AGF MUST support Transport Network Layer Associations as defined in TS 38.412 [15].

[R-41] The AGF SHOULD support multiple TLNAs per AMF and TLNA load balancing.

[R-42] The AGF MUST support dynamic AMF discovery either via DNS (TS29.303 [17]) or statically via OAM based configuration.

[R-43] The AGF MUST support NGAP UE-TNLA-binding as described in 23.501 [26] clause 5.21.

[R-44] The AGF MUST support NGAP as defined for W-AGF (3GPP terminology for AGF) in TS 29.413 [18].

[R-45] The AGF (acting as a NG RAN as defined in TS 38.413 [16] and for the features to be supported by a Non 3GPP AN as defined in TS 29.413 [18]) MUST support maintaining up-to-date information of the AMFs it is connected to, in terms of:

- Served GUAMIs
- Backup AMF name
- Supported network slices
- Relative capacity
- Overload status
- Operational status.

6.8 AGF support for slicing and AMF selection

This section specifies the requirements for AGF support of slicing and AMF selection.

The AGF makes use of the Requested NSSAI and GUAMI to select an AMF. For FN-RG, in the current issue of specification, the AGF does not need the Requested NSSAI to select the AMF.

While for a FN-RG these parameters have to be set or retrieved directly by the AGF, for a 5G-RG, the AGF retrieves them within EAP-5G (see sections 8.2.1 and 8.2.2) sent by the 5G-RG itself. In case the 5G-RG

does not send any of these parameters or the corresponding AMF(s) cannot be determined or reached, then the AGF might end up with selecting an AMF among a set of default AMFs.

The 5G-RG or the AGF acting as a UE on behalf of a FN-RG and the AGF acting as a 5G AN follow the 5GC procedures specified by 3GPP for network slicing (specified in TS23.501 [26] clause 5.15).

[R-46] As a 5G AN, the AGF MUST support AMF selection as specified by TS 23.501 [26] clause 6.3.5 (AMF discovery and selection), clause 5.15 (Slice impacts on AMF selection).

[R-5G-57] If the AGF can reach an AMF corresponding to the GUAMI received from the 5G-RG in the EAP-Response (refer to TS 23.316 [23] clause 7.2.1.1 5G-RG registration procedure via W-5GAN or TS 23.316 [23] clause on Service Request), then the AGF MUST run the NGAP Initial UE procedure to establish an NGAP association for the 5G-RG with this AMF and forward the NAS signaling received from the 5G-RG to this AMF over N2. Otherwise, the AGF MUST select an AMF based on the requirements [R-5G-59] and [R-5G-60].

[R-5G-58] The AGF MUST support GUAMI identifying an individual AMF or GUAMI identifying multiple AMF(s) (within an AMF set).

[R-5G-59] If the AGF cannot reach an AMF corresponding to the GUAMI received by the 5G-RG in the EAP-Response or does not receive a GUAMI from the 5G-RG, then as specified by TS 23.501 [26] clause 5.15, the AGF MUST select an AMF on the basis of the Requested NSSAI, and run the NGAP Initial UE procedure (as defined in TS 29.413[18]/38.413[16]) to establish an NGAP association for the 5G RG with this AMF and forward the NAS signaling received from the 5G-RG.

[R-5G-60] If the AGF is not able to select an AMF based on the Requested NSSAI or based on the GUAMI received from the 5G-RG in the EAP-Response or does not receive these parameters from the 5G-RG, then the AGF MUST select from a set of default AMFs (configured locally) and run the NGAP Initial UE procedure (as defined in TS 29.413[18]/38.413[16]) to establish an NGAP association for the 5G RG with this AMF and forward the NAS signaling received from the 5G-RG.

[R-47] The AGF MUST be able to receive over N2 from current AMF the request to redirect a an Initial NAS message to a different AMF, according to the Reroute NAS Request procedure defined in clause 8.6.5 of TS 38.413 [16].

[R-FN-26] The AGF MUST store the GUAMI of the serving AMF when the N2 connection for the RG is established.

[R-FN-27] When the AGF performs a Registration procedure on behalf of a FN-RG, the AGF SHOULD NOT provide any Requested NSSAI.

Note: If the AGF is not configured with Requested NSSAI, the operator MUST ensure that there is a single default S-NSSAI provisioned to the UDM for the FN-RG. The AMF will register only that default S-NSSAI and include it in Allowed NSSAI.

[R-FN-28] When the AGF performs a PDU SESSION ESTABILISHMENT REQUEST (documented in clause 7.3.4 of TS 23.316 [23]) on behalf of a FN-RG, the AGF SHOULD provide as S-NSSAI the Allowed S-NSSAI that the 5GC indicated in the REGISTRATION ACCEPT.

Note: this requirement might change in a future issue of this specification with the support of multiple PDU sessions.

[R-FN-29] The AGF SHOULD NOT include any DNN in the PDU SESSION ESTABLISHMENT REQUEST documented in clause 7.3.4 of TS 23.316 [23].

Note: The network operator MUST ensure that a default DNN is provisioned for the default S-NSSAI of the FN-RG's UDM record. The AMF will use that DNN for the PDU session.

Note: this requirement might change in a future issue of this specification with the support of multiple PDU sessions.

If a change in the subscription information occurs that implies a slice-specific authentication and authorization failure or revocation, as documented in TS 24.501 clause 5.5.2.3.1, the AGF as proxy UE will be requested from the 5GC to de-register the FN-RG via a DEREGISTRATION REQUEST, which indicates the rejected NSSAI IE. The 5GC also indicates whether a re-registration is needed or not.

[R-FN-30] The AGF MUST support NETWORK-INITIATED DEREGISTRATION procedure due to slice-specific authentication and authorization failure or revocation, as documented in TS 24.501 clause 5.5.2.3.1. In case the NETWORK-INITIATED DEREGISTRATION REQUEST indicates that a re-registration is needed, the AGF MUST start a new Registration.

If a change in the subscription information about the DNN associated with the Allowed NSSAI occurs, the AGF as proxy UE will be requested from the 5GC to release the PDU session via a NETWORK-INITIATED PDU SESSION RELEASE REQUEST.

[R-FN-31] The AGF MUST support a NETWORK-INITIATED PDU Session release procedure due to slice specific authorization failure. After the PDU session release, the AGF SHOULD initiate PDU session.

6.9 Connection Management State on AGF

When the AGF operates as proxy UE, it maintains both a Connection Management state and a Registration Management state on behalf of the FN-RG. With regards to the change of states, the following requirements apply:

[R-FN-32] The AGF SHOULD supervise the wireline connectivity in cases of IP session initiation with PPPoE and in cases of IP session initiation with IPoE.

[R-FN-33] Upon detecting a loss of connectivity on the IP session, the AGF SHOULD start the AN Release procedure as documented in TS 23.316 [23] clause 7.2.5.3 and in clause 8.1.12 (FN-RG AN Release via W-5GAN).

Note: Alternatively, the AGF may initiate the De-Registration Procedure as specified in section 8.1.9.

[R-FN-34] Upon receiving the N2 UE Context Release command from the AMF, the AGF SHOULD flush the FN-RG N2 context, keeping the N1 context until the non-3GPP Implicit Deregistration timer expires.

[R-FN-35] Upon receiving the N2 UE Context Release command from the AMF, the AGF proxy NAS termination that acts on behalf of the FN-RG SHOULD change state from (RM-REGISTERED, CM-CONNECTED) to (RM-REGISTERED, CM-IDLE) and SHOULD start the non-3GPP Implicit Deregistration timer, using the default value or the value received from by the AMF in the in NAS Registration Accept message (as documented in TS 24.501 [11] clause 8.2.7.17). When this timer expires, the AGF SHOULD enter the (RM-DEREGISTERED, CM-IDLE) state and flush the local 3GPP context.

[R-FN-36] If the wireline connectivity is restored prior to the expiry of the AGF Implicit Deregistration timer, the AGF proxy NAS termination SHOULD issue a Service Request on behalf of the FN-RG on the N1 interface to restore the set of PDU sessions active at the time of the outage, avoiding a new Registration on 5GC. Upon resuming the PDU sessions, the AGF SHOULD transition back to the (RM-REGISTERED, CM-CONNECTED) state.

[R-FN-37] If the wireline connectivity is restored after to the expiry of the AGF Implicit Deregistration timer, the AGF SHOULD start a NAS initial Registration procedure, as documented in TS 23.316 [23] Clause 7.2.1.3 and section 8.1.6 (Registration Management Procedure for FN-RG).

Implementation dependent possible behaviors of the AGF with regards to the CM and RM states are described in the Appendix “Mitigating the Impact of Outages” in TR-470 [9].

6.10 Detection of FN-RG equipment change

[R-FN-38] Upon receipt of a PPPoE PADI for a given Line ID, if the FN-RG is in the RM-REGISTERED state, the AGF MUST check whether the FN-RG MAC in the PADI message corresponds to the MAC address associated with the registration. If different, the AGF performs FN-RG deregistration procedures.

[R-FN-39] Upon receipt of a DHCPv4 discover for a given Line ID, if the FN-RG is in the RM-REGISTERED state the AGF MUST check the client-identifier option 61, if present, or chaddr field in the DHCP discover message against the last registered client-identifier option 61 or chaddr for the FN-RG. If different, the AGF performs FN-RG deregistration procedures.

[R-FN-40] Upon receipt of a DHCPv6 Solicit for a given Line ID, if the FN-RG is in the RM-REGISTERED state the AGF MUST check the DUID field in the DHCP solicit message against the last registered DUID for the FN-RG. If different, the AGF performs FN-RG deregistration procedures.

[R-FN-41] Upon receipt of an ICMPv6 RS (SLAAC) for a given Line ID, if the FN-RG is in the RM-REGISTERED state the AGF MUST check the FN-RG MAC Ethernet header against the last registered MAC for the FN-RG. If different, the AGF performs FN-RG deregistration procedures.

[R-FN-42] When an IP session trigger is received in the RM-DEREGISTERED/CM-IDLE state, the AGF MUST store the identity of the FN-RG gleaned as per [R-FN-38] through [R-FN-40] for the duration of the Registration.

6.11 FN-RG IP session initiation requirements

The following requirements apply when an AGF is performing FN-RG IP session initiation procedures:

[R-FN-43] The AGF, when formulating the PDU Session Establishment Request documented in clause 7.3.4 of TS 23.316 [23] on behalf of an FN-RG, MUST determine the PDU Session Type by a local configuration.

[R-FN-44] With regards to [R-FN-43], the AGF MUST be able to be configured per S-VLAN and per physical interface with a PDU Session Type of IPv4, IPv6 or IPv4v6, such that IPv4v6 SHOULD be the default value.

[R-FN-45] When establishing the PDU session, the AGF MUST conform to the Selected PDU Session Type indicated by the PDU Session Establishment Accept received from the 5GC.

[R-FN-46] The AGF, when formulating the PDU Session Establishment Request documented in clause 7.3.4 of TS 23.316 [23] on behalf of an FN-RG using PPPoE or PPPoL2TP encapsulation, MUST use the Extended Protocol Configuration Option “IP address allocation via NAS signaling”.

[R-FN-47] The AGF, when formulating the PDU Session Establishment Request documented in clause 7.3.4 of TS 23.316 [23] on behalf of an FN-RG using IPoE encapsulation, MUST not request IP addressing via NAS signaling. In the PCO container the AGF MUST explicitly indicate its willingness to have a deferred IPv4 address allocation.

[R-FN-48] If when the IP session has been initiated with PPPoE or PPPoL2TP, the PDU Session Establishment Accept indicates that FN-RG is not allowed to use IPv4 stack (Selected PDU Session Type=IPv6), the AGF MUST reply to the FN-RG IPCP Configuration Request with an LCP Protocol Reject.

[R-FN-49] If when the IP session has been initiated with PPPoE or PPPoL2TP, the Session Establishment Accept indicates that FN-RG is not allowed to use IPv6 stack (Selected PDU Session Type=IPv4), AGF MUST reply to the FN-RG IPv6CP Configuration Request with an LCP Protocol Reject.

[R-FN-50] When the IP session has been initiated with PPPoE or PPPoL2TP, the AGF MUST assign the IPv4 address received from the 5GC in the PDU Session Establishment Accept to the FN-RG when replying to the FN-RG IPCP Configuration Request.

[R-FN-51] When the IP session has been initiated with PPPoE or PPPoL2TP, the AGF MUST NOT acknowledge the initial IPv6CP Configuration Request sent by the FN-RG, replying with a Configuration-Nak.

[R-FN-52] In the IPv6CP Configuration-Nak specified in [R-FN-51], the AGF MUST assign to the FN-RG the Interface Identifier received from the 5GC in the PDU Session Establishment Accept.

[R-FN-53] When the IP session has been initiated with PPPoE or PPPoL2TP, and the FN-RG is allowed to use IPv6 stack (Selected PDU Session Type=IPv6 or IPv4v6), the AGF MUST send an IPv6CP Configuration Request to FN-RG, self-assigning as Interface Identifier the SMF LLA information received from the 5GC in the PDU Session Establishment Accept.

Note: This needs to be confirmed with 3GPP and will be updated in a future revision of this document.

[R-FN-54] The AGF MUST forward the Router Advertisement containing the IPv6 Prefix assigned to the FN-RG by the 5GC.

Note: RFC 4861 [47] would require the 5GC to start sending RAs as soon as possible. This will occur in parallel to any DHCPv6 exchange and start as soon as a PDU session is set up as the SMF is the source of RAs. Therefore, RAs will occur in advance of or in parallel with DHCPv6 exchange.

[R-FN-55] If the Router Advertisement specified in [R-FN-54] includes the Source Link-Layer Address Option and the FN-RG uses PPPoE or PPPoL2TP encapsulation, the AGF MUST remove the option before forwarding the RA message to the FN-RG.

[R-FN-56] If the FN-RG allowed session type is IPv6 or IPv4v6, the AGF SHOULD forward any Router Solicitation sent by the FN-RG to the 5GC.

[R-FN-57] If the access protocol suite is IPv6oE and the Router Solicitation sent by the FN-RG as specified in [R-FN-56] contains the Source Link-Layer Address Option, the AGF SHOULD remove it before sending the message to the SMF.

[R-FN-58] The AGF MUST relay the DHCPv6 messages exchanged between 5GC and the FN-RG if the session type is IPv4/IPv6 or IPv6.

Note: [R-FN-54], [R-FN-55], [R-FN-56], [R-FN-57] and [R-FN-58] apply to both session initiation and maintenance throughout session lifetime

For FN-RG procedures, the Line ID information is a requirement for Registration and PDU Session Initiation. As described in TR-470 section 7.1, the Line ID is derived from metadata added by deployed access equipment that allows the client-facing interface to be identified. This metadata information is inserted by the Access Node in every eligible message transmitted by the FN-RG to initiate an IP session (including PPPoE PADI and PADR, Router Solicitation, DHCPv4 control packets such as DISCOVER, REQUEST, etc. and DHCPv6 control packets such as SOLICIT, REQUEST, etc.).

In the FN-RG IP session initiation procedures described in the section 8.1, the Access Node must be configured to add the relevant metadata necessary to derive the FN-RG Line ID. This is actually a necessary condition, without which the AGF cannot serve FN-RGs.

Depending on the encapsulation protocol used and possibly on the type(s) of IP stack(s) requested by the FN-RG, the following cases can occur:

1. FN-RG uses PPPoE encapsulation – In this case, the Access Node must support the PPPoE Intermediate Agent function, as FN-RG uses PPPoE encapsulation – specified in TR-101 issue 2 section 3.9.2 and 3.9.3. This is a necessary condition to allow the AGF to serve an FN-RG that requests the IPv4 stack or the IPv6 stack or both using PPPoE protocol.
2. FN-RG uses PPPoE encapsulation and the backhaul to the AGF uses L2TP – In this case, the Access Node must support the PPPoE Intermediate Agent function. The L2TP Access Concentrator opening the L2TP tunnel is required to add the Circuit ID AVP and/or the Remote ID AVP extracted from the PPPoE messages to the ICRQ message, as per RFC 5515 [57], sent to the L2TP Network Server (LNS) serving as an AGF.
3. FN-RG uses IPoE encapsulation – In this case, the Access Nodes must support:
   a. The Layer2 DHCP Relay Agent function, as specified in TR-101 issue 2 section 3.9.1 and 3.9.3. This is a necessary condition to allow the AGF to serve an FN-RG that requests the IPv4 stack using DHCPv4 protocol.
   b. The Lightweight DHCPv6 Relay Agent (LDRA) function, as specified in TR-177 Issue 1 Corrigendum 1 section 5.6.1 and as per RFC 6221 [54]. This is a necessary condition to allow the AGF to serve an FN-RG that requests the IPv6 stack directly using DHCPv6 protocol.
   c. The Line Identification Option (LIO) insertion in the Router Solicitation messages as requested by TR-177 Issue 1 Corrigendum 1 and as per RFC 6788 [55]. This is a necessary condition to allow the AGF to serve an FN-RG that requests the IPv6 stack using SLAAC. Notice that subsequently the FN-RG could use DHCPv6 protocol to request a Delegated Prefix.

   Note: For FN-RGs not using PPPoE encapsulation, there is not uniform behavior about the use of a Router Solicitation (RS) or a DHCPv6 Solicit as a first indication of the intention to establish an IPv6 session: some FN-RGs require receipt of an RA prior to initiating DHCPv6 procedures, some others send a DHCPv6 Solicit message without having received any RA.

Any order in the stack requests by the FN-RG is possible: a dual-stack FN-RG might request IPv4 stack prior to IPv6 or vice versa, and it might also request only one of the two stacks.

A dual-stack FN-RG using PPPoE encapsulation will indicate the intention to initiate an IPv4 IP session using an IPCP Configuration Request and the intention to initiate an IPv6 IP session using an IPv6CP Configuration Request: both types of requests are sent within the context of the same PPP session. The AN will insert the metadata necessary to derive the FN-RG Line ID in the PADI and PADR messages that initiate the session. Therefore the metadata are inserted once, independently on the number and the order of the stacks requested by the FN-RG.

For a dual-stack FN-RG using IPoE encapsulation, there is not an underlying layer that binds the stack requests coming from the same FN-RG. The FN-RG will indicate the intention to initiate an IPv4 IP session using a DHCPv4 Discover and the intention to initiate an IPv6 IP session using either a DHCPv6 Solicit or a Router Solicitation possibly followed by a DHCPv6 Solicit. The AN, on its part, will insert the metadata necessary to derive the FN-RG Line ID in each eligible upstream control packet that initiates a request for a stack. For a dual-stack FN-RG, that means the AN will insert the metadata:

- in the DHCPv4 Discover message and in the RS message, or
- in the DHCPv4 Discover message and in the DHCPv6 Solicit message, or
- in the DHCPv4 Discover message, in the RS message and in the DHCPv6 Solicit message (if any).

Note: Receiving independent messages with common Line ID allows the AGF to discriminate households even if the N:1 VLAN model is used. In case of 1:1 VLAN model, the logical interface on the access side where the various initiation messages are received would be sufficient to allow the AGF to correlate the independent session initiation procedures with a common subscription and PDU session.

Given the AN behavior and the different encapsulation types the FN-RG might use, the AGF will have to handle all possible cases with regard to the type and the order of IP stack requests.

In issue 1 of this specification, at most one IPv4 and one IPv6 stack per FN-RG are allowed and only one PDU session per FN-RG is supported. To accomplish that:

1. For FN-RG using PPPoE encapsulation, it is sufficient that the AGF limits to one the number of PPPoE sessions granted to the RG, as there is a one-to-one association between the PPPoE session (possibly with both IPv4 and IPv6 NCPs open) and the PDU session;
2. For FN-RG using IPoE encapsulation, it is necessary the AGF limits to one the number of PDU sessions requested to the 5GC, independently of the number of stacks requested by the FN-RG. This means the first requested stack triggers the PDU session establishment for the one PDU session, the second stack (if allowed) will share the same PDU session.

If the FN-RG state is RM-DEREGISTERED/CM-IDLE on the AGF, any message initiating an IP session (PADI, DHCPv4 Discover, DHCPv6 Solicit, Router Solicitation) sent by the FN-RG will trigger the registration as well as the PDU session establishment procedure on the AGF. By means of the reply to the latter request, the AGF is made aware of the types of IP stacks the user subscription permits and maps the allowed IP sessions with a single PDU session, supporting those stacks. While the FN-RG is in RM-REGISTERED state on the AGF, any other message initiating an IP session never triggers a new registration.

Once in RM-REGISTERED state, the FN-RG may transition between CM-IDLE and CM-CONNECTED states as explained in section 6.9 (Connection Management State on AGF). The transitions may be triggered not only by detected changes in the wireline connectivity, but also by the receipt of a new PADI, or DHCPv4 Discover, or DHCPv6 Solicit, or Router Solicitation.

When detecting one of these messages, the AGF tries to figure out if there has been a change of the FN-RG equipment, checking one or more of the following information fields (if present): the source MAC address at the Ethernet layer of the packet, the Option 61 or the Client Hardware field (alias chaddr) in the DHCPv4 Discover, the DHCP Unique Identifier (alias DUID) in the DHCPv6 Solicitation, the FN-RG Link Local Address (LLA) and any other indication that it may be useful to the scope.

In the following text, the information used by the AGF to identify the specific FN-RG is termed as “customer equipment identifier” irrespective of the source parameter used (for example, the MAC address, option 61 client-identifier, or DUID).

If the FN-RG state is RM-REGISTERED/CM-IDLE on the AGF, a message initiating an IP session (PADI, DHCPv4 Discover, DHCPv6 Solicit, Router Solicitation) sent by the FN-RG triggers the AGF NAS proxy acting on behalf of the FN-RG to perform the Service Request Procedure, if the customer equipment identifier is the same used for the Registration.

Besides triggering the Service Request Procedure, the AGF establishes the requested IP session(s) and restores the user plane continuity between the GTP-U on the network side and the IP session(s) on the access side. At the end, the FN-RG state on the AGF is RM-REGISTERED/CM-CONNECTED. Else if the customer equipment identifier of the packet initiating the new IP session is different from the one used for the Registration, the AGF triggers a De-Registration and enters the RM-DEREGISTERED/CM-IDLE state. Subsequently, the AGF can register the FN-RG and issue a PDU session establishment again, moving to RM-REGISTERED/CM-CONNECTED state.

If the FN-RG state is RM-REGISTERED/CM-CONNECTED on the AGF, it means the AGF has in place at least an IP session mapped to a PDU session. If it receives a message initiating an IP session (PADI, DHCPv4 Discover, DHCPv6 Solicit, Router Solicitation) from the FN-RG, this might be the sign of one of a number of different scenarios. Here a distinction is needed on the basis of the FN-RG encapsulation.

1. FN-RG using PPPoE encapsulation – The new PADI can be an indication of a change of the FN-RG device, or an indication of the restoration from a fault not-detected by the AGF, or an indication of a second PPP request from the same household.
    - If the customer equipment identifier is different from the one used for Registration, then the AGF assumes the customer has changed FN-RG device. The AGF will therefore trigger a De-Registration and enter the RM-DEREGISTERED/CM-IDLE state. Subsequently, the AGF can register the FN-RG and issue a PDU session establishment again, moving to RM-REGISTERED/CM-CONNECTED state.

- If the customer equipment identifier is the same used for Registration, then the AGF may issue immediately an ICMP echo request to check the liveliness of the FN-RG on the PPP session already in place. If it receives a reply, then the AGF assumes the PADI as a new session request and it will ignore it. If it does not receive any reply, then the AGF assumes the PADI as an indication of the restoration from an undetected fault.

  In the latter case, the default behavior of the AGF is performing a De-Registration followed by a new Registration and a new PDU session establishment request.

  Optionally, when the AGF becomes aware of an undetected fault, the AGF may setup a new PPP session with the same information context of the previous PPP session and map it to the PDU session already in place.

  As an alternative to the use of ICMP echo requests, the AGF may simply wait for the pre-existing session LCP Echo Requests to expire. A PADI received in the CM-CONNECTED case is silently discarded.

  In all cases, the FN-RG ends up in the RM-REGISTERED/CM-CONNECTED state.

2. FN-RG using IPoE encapsulation – The new DHCPv4 Discover or DHCPv6 Solicit or Router Solicitation can be an indication the FN-RG requests to add a new stack, or an indication of a change of the FN-RG device, or an indication of the restoration from a fault not-detected by the AGF, or an indication of a second IP session request from the same household.

   - If customer equipment identifier is different from the one used for Registration, then the AGF assumes the customer has changed FN-RG device. The AGF will therefore trigger a De-Registration and enter the RM-DEREGISTERED/CM-IDLE state. Subsequently, the AGF can register the FN-RG and issue a PDU session establishment again, moving to RM-REGISTERED/CM-CONNECTED state.
   - If customer equipment identifier is the same used for Registration and the message initiates a different type of stack, then the AGF may simply map the IP session to the existing PDU session, if this is IPv4v6 type.
   - If customer equipment identifier is the same used for Registration and the AGF has already mapped the requested IP stack with the PDU session, the new message will be handled by the IP addressing function of the 5GC. It is assumed this function will limit the IP addresses and IPv6 prefixes assigned to the FN-RG aligning with the number of PDU session requested by the AGF (which in this specification issue is limited to one). It is also assumed this function behaves as a standard DHCPv4/DHCPv6 server and therefore gracefully accepts renegotiation without any N1 signaling.
     Optionally, when the AGF becomes aware of an FN-RG renegotiation intention, the AGF may perform a De-Registration followed by a new Registration and a new PDU session establishment request.

The following requirements codify the description above:

[R-FN-59] The AGF MUST limit the PDU sessions in place for an FN-RG to one.

[R-FN-60] The AGF MUST limit to one the number of PPP sessions for the same FN-RG.

Note: The restrictions expressed in [R-FN-59] and [R-FN-60] will be reconsidered in future issues of this specification.

[R-FN-61] The AGF MUST be able to map the IPv4 and IPv6 IP sessions initiated by the same FN-RG to a common IPv4v6 PDU session.

[R-FN-62] If the FN-RG state is RM-DEREGISTERED on the AGF, and if the AGF receives a message initiating an IP session (and in the case of PADI, subsequent exchange until the RG type can be ascertained by LCP exchange), the AGF MUST perform the Registration and the PDU session establish procedures on behalf of the FN-RG.

Note: the messages initiating an IP session can be the following: PPPoE PADI, DHCPv4 Discover, DHCPv6 Solicit, or ICMPv6 Router Solicitation.

[R-FN-63] If the FN-RG state is RM-REGISTERED/CM-IDLE, if the AGF receives a message initiating an IP session and the customer equipment identifier is the same used for the Registration, then the AGF SHOULD perform the Service Request procedure on behalf of the FN-RG.

Note: the messages initiating an IP session can be the following: PPPoE PADI, DHCPv4 Discover, DHCPv6 Solicit, or ICMPv6 Router Solicitation.

[R-FN-64] If the FN-RG state is RM-REGISTERED/CM-IDLE and the FN-RG uses IPoE encapsulation, if the AGF detects a resumption of traffic from the FN-RG, then the AGF SHOULD perform the Service Request procedure on behalf of the FN-RG.

[R-FN-65] When negotiating the stacks for the FN-RG, the AGF MUST conform to the Selected PDU Session Type indicated by the PDU Session Establishment Accept received from the 5GC.

[R-FN-66] While the FN-RG state is RM-REGISTERED/CM-CONNECTED on the AGF, if the AGF has in place an IP session mapped to an IPv4v6 PDU session and receives from the FN-RG a message initiating a different stack, the AGF MUST add the second stack to the mapping as per [R-FN-61].

[R-FN-67] While the FN-RG state is RM-REGISTERED/CM-CONNECTED on the AGF and the FN-RG uses IPoE encapsulation, if the AGF receives a trigger to initiate an IP session for a protocol not supported by the PDU session type, the AGF will silently discard the message.

[R-FN-68] While the FN-RG is in the RM-REGISTERED state on the AGF, if the FN-RG has initiated an IPv6 session via an RS or a DHCPv6 Solicitation and in the PDU SESSION ESTABLISHMENT ACCEPT the 5GC indicates that FN-RG is not allowed to use the IPv6 stack (Selected PDU Session Type=IPv4), the AGF SHOULD not deregister the FN-RG.

[R-FN-69] While the FN-RG is in the RM-REGISTERED state on the AGF, if the FN-RG has initiated an IPv4 session via a DHCPv4 Discover and in the PDU SESSION ESTABLISHMENT ACCEPT the 5GC indicates that FN-RG is not allowed to use the IPv4 stack (Selected PDU Session Type=IPv6), the AGF SHOULD not deregister the FN-RG.

6.12 Authentication for FN-RG

[R-FN-70] An AGF SHOULD always respond to a PAP Authenticate-Request with an Authenticate-ACK.

[R-FN-71] An AGF MUST initiate a CHAP Challenge to the PPP peer. Upon receipt of the CHAP Response, an AGF SHOULD always respond with a CHAP Success.

[R-FN-72] An AGF MUST set “Authenticated Indication” flag in N2 Initial UE Message towards AMF indicating that the FN-RG is authenticated by AGF. Please refer to clause 7.2.1.3 of TS 23.316 [23].

Note: FN-RG Authentication using PPP Authentication (PAP or CHAP) by 5G Control Plane is for FFS. This is beyond the existing authentication of the FN-RG using the GLI.

Note: How the AGF should handle the case where the 5GC does not accept the Registration Request on behalf of an FN-RG will be specified in a next issue of this specification.

6.13 Combined AGF/UPF

AGF and UPF functions can be combined into a single implementation. The UPF is then called “co-located”. Co-location happens on a per PDU session basis. This model is described in detail in TR-470 section ‘Combined AGF/UPF’, including the concept of AGF identities parameter (WAgfInfo), as defined by 3GPP in TS 38.413 clause 9.2.5.3 [16] and TS 29.510 [20].

[R-48] The AGF SHOULD support UPF co-location (a.k.a. Combined AGF/UPF) by inserting its identity to the WAgfInfo parameter to UPLINK NAS TRANSPORT messages on N2 interface.

[R-49] When an AGF does not support UPF co-location, it MUST NOT send the WAgfInfo parameter to the AMF.

When the AGF supports UPF co-location, the following requirements apply:

[R-FN-73] The AGF MUST support sending the WAgfInfo parameter to AMF over N2, as part of session management, as described in TS 23.316 [23] clause 7.3.4 (step 2).

[R-FN-74] The AGF MUST NOT send the WAgfInfo parameter to AMF in any other messages than the N2 message transporting the PDU Session Establishment Request.

[R-5G-61] The AGF MUST support sending the WAgfInfo parameter to AMF in all N2 messages.

[R-50] The AGF MUST support UPF as specified in TS 23.501 [26], based on the specific aspects linked to wireline access described in TS 23.316 [23].

[R-51] The AGF MUST support an externally connected UPF via an N3 interface to support the case where SMF does not select the co-located UPF.

7 Migration consideration

Operational simplicity for support of migration and reverse migration between FN-RGs and 5G-RGs is achieved by the deployment of an AGF that supports both direct and adaptive modes of operation and can auto-sense the class of CPE that is currently connected to a subscriber drop.

Autosensing of the CPE is a feature of the protocol design such that the initiation of 5G-RG registration procedures can be distinguished from FN-RG session initiation. Similarly, the procedures have been designed such that a 5G-RG can detect if it is being served by an AGF or a legacy BNG.

The AGF then tracks the CPE class on a per Line ID basis. This is formally described in section 7.1 (The Line ID based state machine).

7.1 The Line ID based state machine

An AGF that is configured to support both Direct and Adaptive modes maintains a state table for each Line ID. This does not have to be persistent across AGF restarts as it is assumed that upon failure followed by restoration the RG will reinitiate either registration or session initiation procedures and therefore identify the class of CPE to the AGF. The Line ID is considered to be invariant through the migration process as it is unaffected by the class of CPE served. It is assumed that only one class of CPE may be connected to an access facility identified by a Line ID at any one time.

When FN-RG based subscribers are initially migrated to the 5GC but prior to CPE upgrade, the UDM will be prepopulated with subscription information where each subscription is indexed by a SUPI constructed from the associated Line ID, or IMSI based SUPI for which the Line ID is used as pseudonym. At this point, the subscriber connectivity in the access network may be re-directed to a standalone AGF, either via network provisioning, or steering to an AGF implemented internal to a BNG.

At the time of forward migration an independent subscription record is created in UDM with a SUPI created from the IMSI of the 5G-RG. Alternatively, the existing IMSI based SUPI can be reused to identify also the 5G-RG subscription. At this point the migration (and possible reverse migration) process between the specifically identified 5G-RG and an FN-RG becomes fully automated and may occur with no further network provisioning. This enables a customer self-install model.

The state machine involves three states:

A. Class of CPE is unknown.

B. Class of CPE is FN-RG

C. Class of CPE is 5G-RG

A transition from a previous known CPE state to another state includes the explicit or implicit de-registration of the CPE in the previous known state. For example, if a Line ID was in the FN-RG state and the AGF detected the initiation of 5G-RG registration procedures, it would de-register the FN-RG subscription.

The actual state machine implemented per Line ID in the AGF is illustrated in Figure 9:

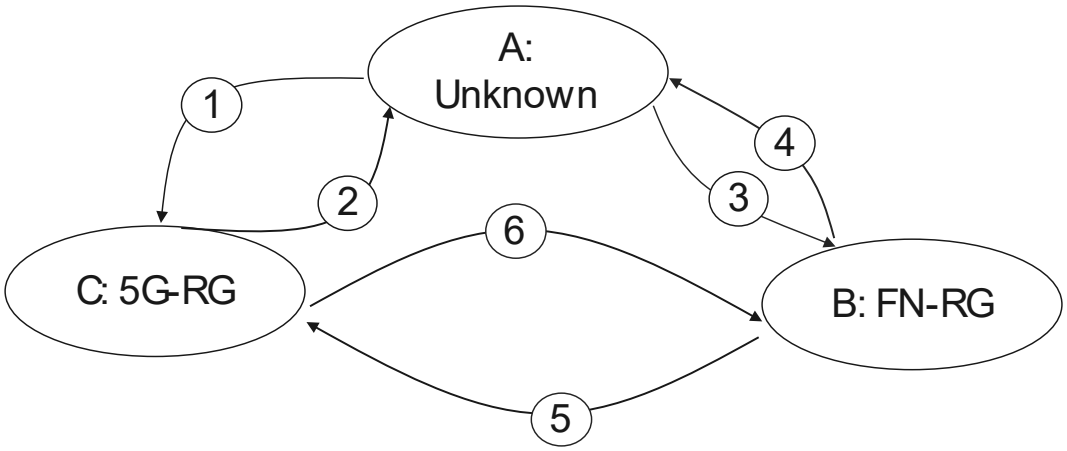


Figure 9: AGF per Line ID State Machine

A direct C-B transition can only occur when an FN-RG authoritatively indicates it is initiating an IP session and this has occurred prior to the AGF detecting a loss of the CP PPPoE session connectivity, which implies a loss of NAS connectivity between the 5G-RG and the AMF. This is achieved if the FN-RG initiates a PPPoE session without the LCP 5G VSO present during LCP negotiations. In this scenario the AGF reports loss of the wireline connectivity to the AMF via an N2 Context Release Request and the AMF starts the deregistration timer for the 5G-RG. In parallel, the AGF starts the FN-RG registration.

Table 3 details the set of triggers for a state transition between the states shown in Figure 9:

#	Transition	Trigger (external from AGF)	AGF Action	Result
1	Unknown → 5G-RG	5G-RG uses PPPoE with LCP 5G VSO option to initiate registration procedures	AGF detects NAS received from the RG, Relays NAS between the 5G-RG and the 5GC and then receives a N2 Initial UE context from the 5GC that induces a transition to the 5G-RG mode (5G RG has been duly authenticated by 5GC)	5GC: 5G-RG is in RM-REGISTERED, CM-CONNECTED state. AGF: RG NAS and UP processing uses direct mode.
2	5G-RG → Unknown	Case 1) 5G-RG performs de-registration procedures Case 2) 5GC initiates de-registration procedures Case 3) Loss of connectivity in the wireline network detected via LCP ECHO	For case 3 AGF reports loss of connectivity to the AMF. Upon reception of N2 UE CONTEXT RELEASE COMMAND from 5GC, the AGF moves the line to the “Unknown” state	(case 1, case 2) 5GC: 5G-RG is put into RM-DEREGISTERED state (Case 3) 5GC: 5G-RG is put into CM-IDLE state and will be deregistered when timer expires.
3	Unknown → FN-RG	FN-RG performs PPPoE (without LCP 5G VSO option) or IPoE session initiation	AGF proxy UE for Line ID performs registration on behalf of FN-RG	5GC: FN-RG is put into RM-REGISTERED, CM-CONNECTED state AGF: RG UP processing uses

				adaptive mode
4	FN-RG → Unknown	Case 1: Abnormal session termination, e.g., AGF detects loss of connectivity with the FN-RG by liveness detection failure (e.g., via LCP, ARP, ICMP, BFD or other protocols) Case 2: Normal session termination, e.g., the IP sessions are explicitly terminated by the FN-RG (e.g., via PPP LCP terminate-request, PPPoE PADT, DHCP release). Case 3: 5GC initiates de-registration procedures	(Case 1) AGF performs the AN Release procedure and starts the De-Registration timer (Case 2): The AGF proxy UE initiates deregistration procedures and moves to CM-IDLE/RM-DEREGISTERED state (Case 3): Upon reception of N2 UE CONTEXT RELEASE COMMAND from 5GC, the AGF proxy UE moves to CM-IDLE/RM-DEREGISTERED state.	(Case 1) 5GC: FN-RG is put into CM-IDLE state and will be deregistered when timer expires. (Case 2) 5GC: FN-RG is put into RM_DEREGISTERED state (Case 3) 5GC: FN-RG is put into RM_DEREGISTERED state
5	FN-RG->5G-RG	5G-RG uses PPPoE with LCP 5G VSO option to initiate registration procedures	AGF proxy UE performs UE based deregistration, and relays NAS from 5G-RG to AMF	5GC: FN-RG is put into RM_DEREGISTERED state 5GC: 5G-RG is put into RM-REGISTERED, CM-CONNECTED state AGF: RG NAS and UP processing uses direct mode
6	5G-RG-> FN-RG	FN-RG initiates PPPoE session without the LCP 5G VSO	AGF reports loss of NAS connectivity to the AMF via an N2 Context Release Request AGF proxy UE for Line ID performs registration on behalf of FN-RG	5GC: 5G-RG is put into CM-IDLE state and deregistration timer started. 5GC: FN-RG is put into RM-REGISTERED, CM-CONNECTED state AGF: RG UP processing uses adaptive mode

Table 3: Triggers for AGF state machine transitions

Note: These are high level transitions, a failure to complete a state change once initiated results in a transition to the “Unknown” state.

Note: In the “Unknown” state, no UP packets or frames are relayed by the AGF

[R-52] An AGF MUST implement the Line ID based state machine as described in Figure 9 and in the Table 3.

8 Procedures and call flows

This section discusses procedures and call flows for FN-RG and 5G-RG. Some AGF-CP/AGF-UP steps which are further described in WT-458 [10] are not shown here.

8.1 For a FN-RG

Note the following procedures only apply to an AGF that has been configured to support adaptive mode. In all the FN-RG IP session initiation procedures documented in this section, for simplicity, the process that allows the AGF to auto-detect the RG operating as FN-RG is not detailed.

> **Note:** The LLA address assignment aspects of these procedures are contingent on 3GPP implementing specific proposals made by the BBF. This will be clarified in a next revision of this document based on 3GPP feedback.

8.1.1 FN-RG IP Session Initiation with PPPoE

Figure 10 shows the call flow for the FN-RG IP session initiation with the AGF based on PPPoE message exchange.

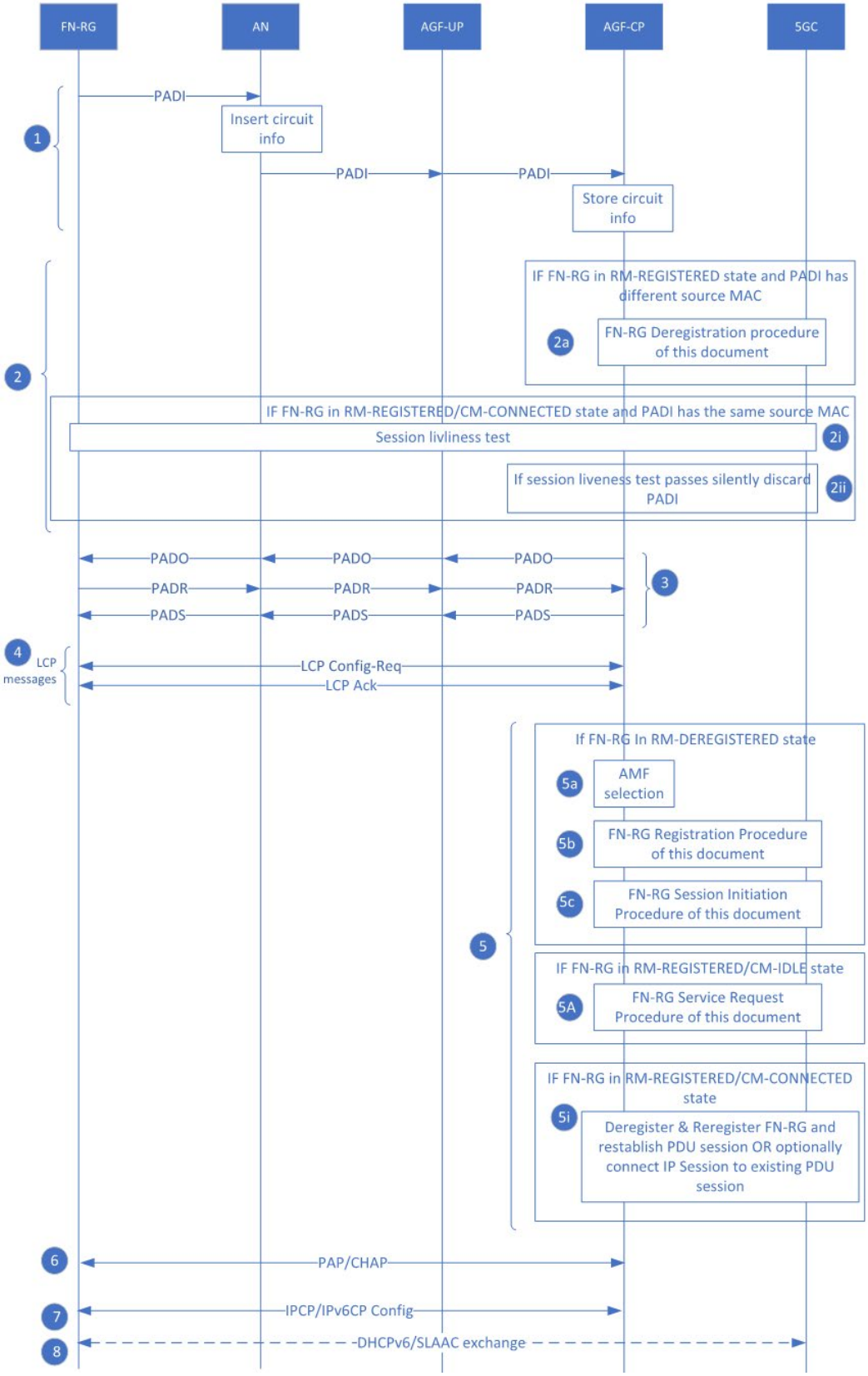


Figure 10: Call flow for FN-RG IP session initiation with PPPoE

1. The FN-RG starts a PPPoE session and begins with a PADI message based on section 5 of RFC 2516 [39].

   The AN receives the PPPoE PADI message and inserts PPPoE tags into the PADI message and forwards the entire message to the AGF-CP. The PPPoE tags include the PPPoE Circuit and Remote ID tag as defined in TR-101 issue 2. This PPPoE tags are treated as Line ID as specified in TR-470 [9].

   On receiving the PADI message, the AGF-CP will store the subscriber's information (FN-RG MAC address, TCI, port & Line ID) obtained from the Ethernet header and PPPoE tags.

2. The AGF will check the validity of the PADI.

   2a. If the MAC address of the FN-RG in the PADI has changed and the FN-RG is in the RM-REGISTERED state, the AGF interprets this as an equipment change and executes the AGF-CP initiated FN-RG Deregistration Procedure described in this document before proceeding to step 3.

   2i. If the MAC address is the same, and the FN-RG is in the RM-REGISTERED state the AGF may ensure this is not a second session initiation by performing an ICMP Ping on any pre-existing session.

   2ii. If the ICMP ping elicits a response from the FN-RG, then this PADI is silently discarded, else the previous IP session is assumed to have failed.

   Note: An alternative technique would be to simply silently discard a PADI received in the RM-REGISTERED/CM-CONNECTED state. This requires the existing LCP-ECHO supervision mechanism to put the existing session into the CM-IDLE state before a PADI is accepted.

3. The PPPoE discovery process completes with the exchange of PADO, PADR and PADS messages between the FN-RG and the AGF.

4. After the PPPoE discovery process completes, both the AGF-CP and FN-RG establish the link layer with LCP packet message exchanges as described in section 5 of RFC 1661 [40].

   The LCP Configure-Request and Configure-Ack messages are exchanged between the FN-RG and AGF-CP via the AN.

   For an FN-RG, there is no 5G Vendor Specific Option (VSO) included in the LCP Configure-Request, and it is the absence of the VSO that permits an FN-RG to be distinguished from a 5G-RG.

5. The AGF will then handle the IP session initiation according to the current registration and connection state:

   If the state is RM-DEREGISTERED

   5a. The AGF-CP selects an AMF as described in section 6.8 (based on TS 23.316 [23], clause 7.2.1.3).

   5b. The FN-RG is registered into the 5GC based on the registration procedure described in section 8.1.6 (based on TS 23.316 [23], clause 7.2.1.3).

   5c. Upon successful registration, the AGF establishes a PDU session as defined in section 8.1.8 (based on TS 23.316 [23] clause 7.3.4). The formulation of PDU SESSION ESTABLISHMENT REQUEST by the AGF proxy NAS termination must adhere to the requirements documented in section 6.11 (FN-RG IP session initiation requirements).

The 5GC, when formulating the reply to PDU SESSION ESTABLISHMENT REQUEST, considers the PDU session type requested by the AGF and the user's subscription data stored in UDM: the latter are authoritative.

From the PDU SESSION ESTABLISHMENT ACCEPT received by the 5GC the AGF learns the type of PDU session that the subscriber is permitted to: this information is in the Selected PDU Session Type field. One of the following three cases occur:

a. If the Selected PDU Session Type is IPv4, the 5GC network provides also an IPv4 address to the AGF. This IPv4 address can be fixed or dynamic, according to the user subscription. The AGF passes this IPv4 address to the FN-RG replying to the FN-RG IPCP Configuration Request and including it as value of the IP Address Option.

b. if the Selected PDU Session Type is IPv6, the 5GC in the PDU SESSION ESTABLISHMENT exchange will support LLA assignment as per the requirements in section 6.3.2.1 (L2/L3 Interworking).

   The AGF will store this information at least until the IPv6CP phase is completed.

c. If the Selected PDU Session Type is IPv4v6, the AGF will use all the information passed by the 5GC in the PDU SESSION ESTABLISHMENT ACCEPT to configure the FN-RG IPv4 address, the FN-RG IPv6 Interface Identifier and its own IPv6 LLA, as explained in the previous items a and b.

If the state is RM-REGISTERED/CM-IDLE

5A. The AGF performs the Service Request Procedure for FN-RG in this document.

If the state is RM-REGISTERED/CM-CONNECTED

5i. The AGF will deregister and re-register the FN-RG and reestablish the PDU session OR MAY simply connect the IP session to the existing PDU session

6. After LCP message exchange (step 4), PAP/CHAP authentication message exchanges also occur between the FN-RG and the AGF-CP and may be in parallel to step 5. The FN-RG is always authenticated by the AGF-CP independently of the PAP password / CHAP challenge response provided by the FN-RG.

7. The FN-RG will then proceed into opening the NCPs for the IP session.

   If the PDU SESSION ESTABLISHMENT ACCEPT indicates that FN-RG is not allowed to use IPv4 stack (Selected PDU Session Type=IPv6), AGF will reply to the FN-RG IPCP Configuration Request with an LCP Protocol Reject. Else in the IPCP phase over PPP the address information obtained from the original PDU SESSION ESTABLISHMENT ACCEPT is provided to the FN-RG.

   If the SESSION ESTABLISHMENT ACCEPT indicates that FN-RG is not allowed to use IPv6 stack (Selected PDU Session Type=IPv4), AGF will reply to the FN-RG IPv6CP Configuration Request with an LCP Protocol Reject and the remaining steps are skipped. Else in the IPv6CP phase over PPP:

   - The FN-RG will typically construct an Interface Identifier and the LLA from the WAN MAC address and offer the Interface Identifier in a Configuration Request. The AGF will not acknowledge the request and will provide the Interface Identifier received from the 5GC.

- The AGF will also send an IPv6CP Configure Request to FN-RG including the Interface Identifier from the SMF LLA information obtained from the PDU SESSION ESTABLISHMENT ACCEPT message.

Note: The LLA of the SMF is not negotiable nor is the assigned FN-RG Interface Identifier provided to the AGF by the SMF.

8. This step might occur only if the IPv6 Interface Identifier gets configured in the IPv6CP phase session. If so, the AGF will pass the IPv6 control traffic exchanged between the FN-RG and the 5GC, changing the encapsulation type from PPP to GTP-U and vice versa. The 5GC will remain responsible for any allocation of IPv6 addresses to the FN-RG, regardless if via SLAAC or DHCPv6. The FN-RG will receive RA and DHCPv6 messages sourced by the SMF LLA; the SMF will receive RS and DHCPv6 messages sourced by the FN-RG LLA.
    a. SLAAC: An ICMPv6 Unsolicited Router Advertisement (RA) containing an IPv6 Prefix (default prefix length is /64) is signaled by the SMF to UPF and sent by UPF to AGF via the downlink GTP-U tunnel associated with the PDU Session. The IPv6 prefix can be fixed or dynamic, according to the user subscription. The AGF-UP forwards the RA to the FN-RG, changing the underlaying encapsulation.

       If the RA from the SMF contains the Source Link-Layer Address Option, the AGF removes it before sending the message to FN-RG.

       Note: any RS message sent by the FN-RG will be forwarded to the 5GC by the AGF, which will change the underlaying encapsulation. If the RS from the FN-RG contains the Source Link-Layer Address Option, the AGF removes it before sending the message to the SMF.

       Note: the AGF may snoop the RA sent by the SMF for troubleshooting and/or security purposes.

    b. DHCPv6: the FN-RG sends a DHCPv6 Solicit containing either a DHCPv6 IA_NA or a DHCPv6 prefix delegation option to request an IPv6 address and/or an IPv6 delegated prefix. The AGF-UP forwards the DHCPv6 messages exchanged between 5GC and the FN-RG, changing the underlaying encapsulation.

Note: the AGF may snoop the DHCPv6 sent by the SMF for troubleshooting and or security purposes.

8.1.2 FN-RG IP session initiation using L2TP

In 5GC interworking, the LNS is replaced by the AGF function which provides the control and user plane for mobile and fixed network traffic. This section outlines the procedural steps for legacy FN-RG interworking between the AGF and existing access nodes implementing an L2TP integration. This section details the authentication and session management procedures.

Note: Unlike the scenarios whereby the AGF is directly connected to an Ethernet ‘V’ interface, the AGF will have no direct visibility of the Ethernet layer. This means the use of the FN-RG MAC address as a PEI and to detect equipment change is not an option.

The Figure 11 shows the full call flow for the registration management of a FN-RG and also session establishment. It utilizes PPPoE concatenated with an L2TP tunnel to start NAS registration with the 5GC, through the AGF interworking.

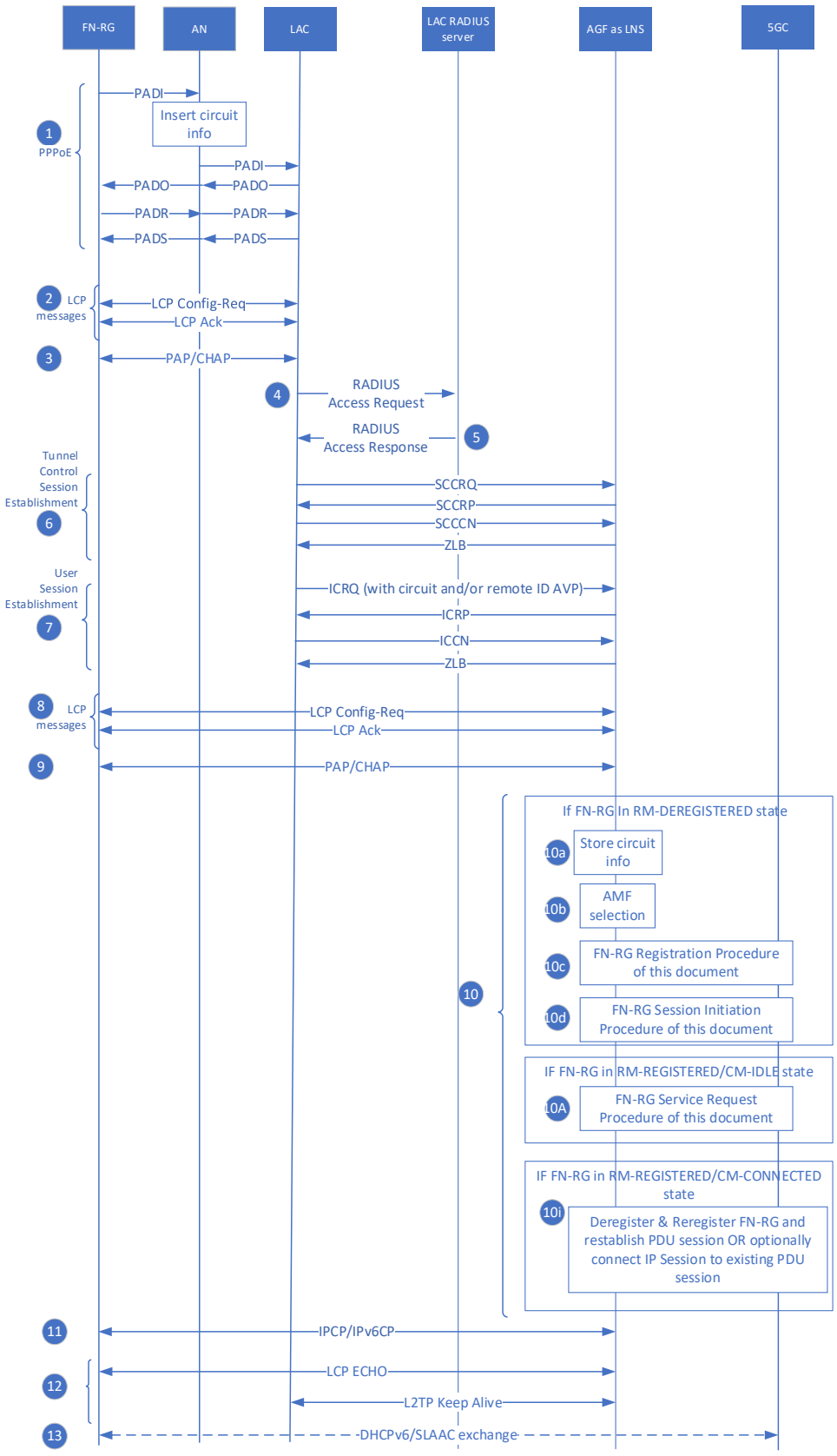


Figure 11: Call flow for the registration management procedure of an FN-RG (Legacy L2TP support).

Procedures:

The procedural steps as documented in Figure 11 follow their respective RFCs. In summary:

1. FN-RG initiates PPPoE client authentication initiation as per RFC 2516 [39] using Agent Remote ID or username as the service identifier, as in TR-101issue 2[ref].

2. PPP Link Control Protocol determines and agrees the standards of the ensuing data transmission, as in RFC 1661 [ref]

3. Authentication challenge (username/password) as (RFC 1661[40] & RFC 1994 [34])

4. LAC generates RADIUS Access Request (RFC 2865 [42])

5. RADIUS response specifies parameters for the L2TP tunnel to be established (RFC 2661 [41], & RFC 2868 [56])

6. L2TP tunnel control session established between LAC and LNS (RFC 2661 [41])

7. L2TP user sessions established between LAC and LNS (RFC 2661 [41])

8. (Optional) LCP re-negotiation procedures may take place with new network and per user parameters, if required, for the data plane; this requires the necessary functionality and can be triggered typically by the LNS device

9. PAP/CHAP authentication completes

10. The AGF will then handle the IP session initiation according to the current registration and connection state:

    If the state is RM-DEREGISTERED

    10a. The AGF-CP stores the circuit information associated with the registration. This would include LAC address, tunnel particulars, and line ID.

    10b. The AGF-CP selects an AMF as described in clause 7.2.1.3 of TS 23.316 [23].

    10c. The FN-RG is registered into the 5GC based on the registration procedure described in section 8.1.6 (based on TS 23.316 [23], clause 7.2.1.3).

    10d. Upon successful registration, the AGF establishes a PDU session as defined in section 8.1.8 (based on TS 23.316 [23] clause 7.3.4). The formulation of PDU SESSION ESTABLISHMENT REQUEST by the AGF proxy NAS termination must adhere to the requirements documented in section 6.11 (FN-RG IP session initiation requirements).

    The 5GC, when formulating the reply to PDU SESSION ESTABLISHMENT REQUEST, considers the PDU session type requested by the AGF and the user's subscription data stored in UDM: the latter are authoritative.

    From the PDU SESSION ESTABLISHMENT ACCEPT received by the 5GC the AGF learns the type of PDU session that the subscriber is permitted to: this information is in the Selected PDU Session Type field. One of the following three cases occur:

    - If the Selected PDU Session Type is IPv4, the 5GC network provides also an IPv4 address to the AGF. This IPv4 address can be fixed or dynamic, according to the user subscription.

The AGF passes this IPv4 address to the FN-RG replying to the FN-RG IPCP Configuration Request and including it as value of the IP Address Option.

- if the Selected PDU Session Type is IPv6, the 5GC in the PDU SESSION ESTABLISHMENT exchange will support LLA assignment as per the requirements in section 6.3.2.1 (L2/L3 Interworking).

  The AGF will store this information at least until the IPv6CP phase is completed.

- If the Selected PDU Session Type is IPv4v6, the AGF will use all the information passed by the 5GC in the PDU SESSION ESTABLISHMENT ACCEPT to configure the FN-RG IPv4 address, the FN-RG IPv6 Interface Identifier and its own IPv6 LLA, as explained in the previous items a and b.

If the state is RM-REGISTERED/CM-IDLE

10A. The AGF performs the Service Request Procedure for FN-RG in this document.

If the state is RM-REGISTERED/CM-CONNECTED

10i. The AGF will deregister and re-register the FN-RG and reestablish the PDU session OR MAY simply connect the IP session to the existing PDU session

11. IPCP configures Internet Protocol over PPP (RFC1332 [31]) and DNS resolver (RFC1877 [33])
12. The user session established, and data exchanged. Periodic PPP and L2TP keepalives are exchanged (RFC 1661[40] / RFC 2661 [41])
13. (Optional IPv6 support) ICMPv6 RS/RA and/or DHCPv6 Exchange may take place to agree on IPv6 addressing requirements for the session

Once a session is established, any changes in parameters, in-flight or through session restarts, arising from the AMF (5GC) will now be handled by AGF similar to any other type of FN-RG.

8.1.3 FN-RG IP Session Initiation with DHCPv4

Figure 12 shows the call flow for the FN-RG IP session initiation with the AGF based on DHCPv4, which subsequently leads to registration and session initiation procedures.

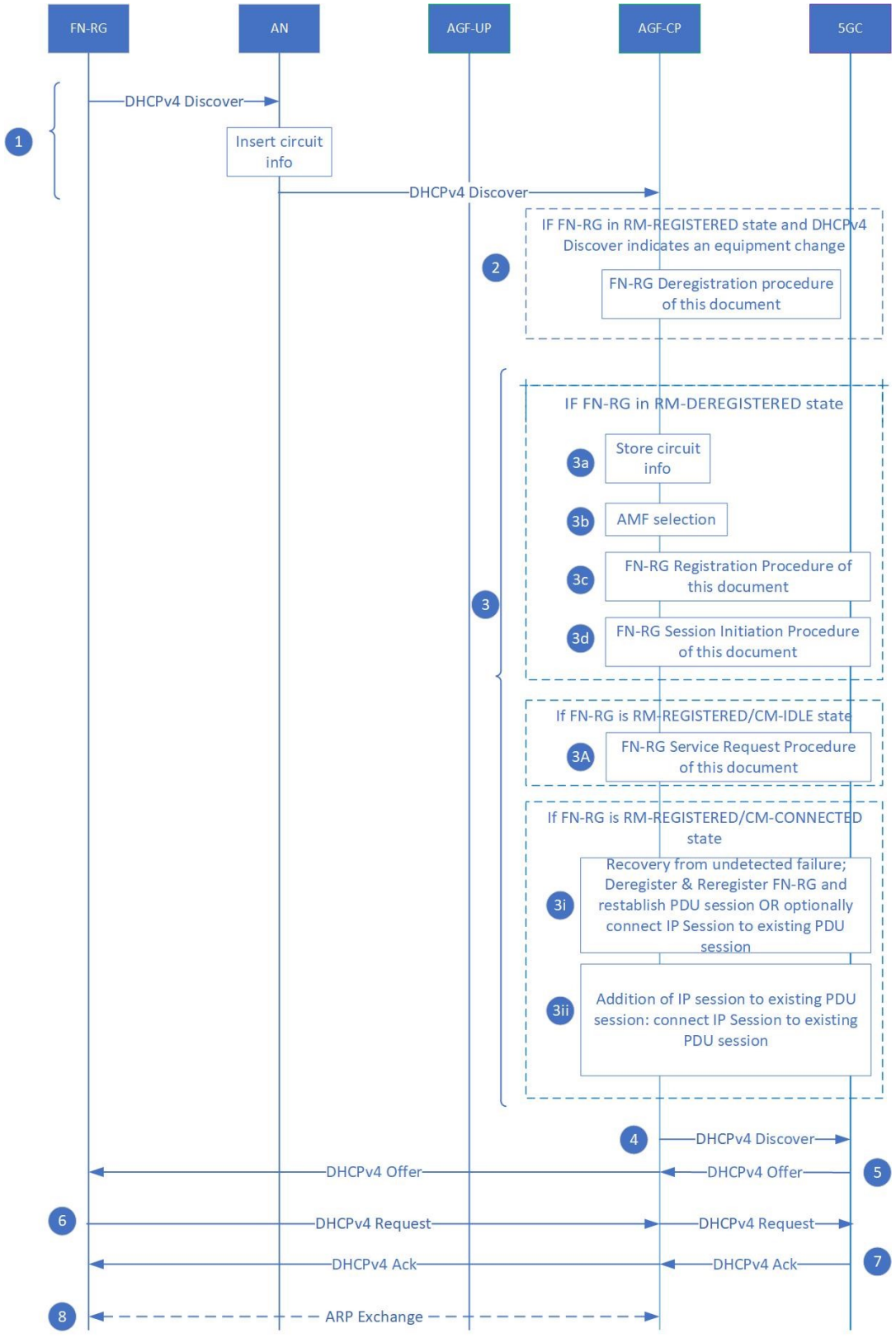


Figure 12: Call flow for FN-RG IP session initiation with DHCPv4

1. The FN-RG sends a DHCPv4 Discover message to the AGF-CP via the AN based on section 5.6.2 of TR-146.

   The AN receives the DHCPv4 Discover message. It inserts Line ID information in option 82 into this message and forwards the entire message to the AGF-CP as per section 3.8.2 of TR-101 Issue2.

2. On receiving DHCPv4 Discover message, if the FN-RG is in the RM-REGISTERED state, the AGF-CP checks the client-identifier option 61, if present, or the RG MAC address. The MAC address may be gleaned from the Ethernet header or from the DHCPv4 chaddr field. If the gleaned information identifying the FN-RG is different than that recorded for the current registration, the AGF interprets this as an equipment change and executes the AGF-CP initiated FN-RG Deregistration Procedure described in this document before proceeding.

3. The AGF will then handle the IP session initiation according to the current registration and connection state:

   If the state is RM-DEREGISTERED:

   3a. The AGF stores the subscriber's information including the FN-RG customer equipment identifier, line identification, TCI, and port identification metadata.

   3b. The AGF-CP selects an AMF as per step 2 in TS 23.316 [23] subclause 7.2.1.3.

   3c. The FN-RG is registered into the 5GC based on the registration procedure described in section 8.1.6 (based on TS 23.316 [23], clause 7.2.1.3).

   3d. A PDU session is established.

   The AGF establishes a PDU session as defined in section 8.1.8 (based on TS 23.316 [23] clause 7.3.4). The formulation of PDU SESSION ESTABLISHMENT REQUEST by the AGF will adhere to the requirements in section 6.11 (FN-RG IP session initiation requirements).

   When the AGF requests PDU session type IPv4v6, it must also facilitate the possible reuse of the PDU session for IPv6 stack. In this case, the AGF will handle the LLA assignment as per the requirements in section 6.3.2.1.

   The PDU session ID is allocated by the AGF.

   The 5GC, when formulating the reply to PDU SESSION ESTABLISHMENT REQUEST, considers the PDU session type requested by the AGF and the user's subscription data stored in UDM: the latter are authoritative.

   From the PDU SESSION ESTABLISHMENT ACCEPT received by the 5GC the AGF learns the type of PDU session that the subscriber is permitted to: this information is in the Selected PDU Session Type field.

   If the Selected PDU Session Type is IPv4or IPv4/v6, the AGF will act as a DHCP Relay for all the DHCPv4 messages from the FN-RG to 5GC. The SMF is responsible for all IPv4 address allocation and network parameters (like Gateway, DNS, etc.).

   If the PDU SESSION ESTABLISHMENT ACCEPT indicated that FN-RG is not allowed to use IPv4 stack (Selected PDU Session Type=IPv6), the AGF will discard the current and any further DHCPv4 messages from that FN-RG on the basis of its Line ID, for the duration of the registration.

   If the state is RM-REGISTERED/CM-IDLE and the selected PDU session type is IPv4 or IPv4/IPv6:

3A. The AGF performs the Service Request Procedure for FN-RG in this document.

If the state is RM-REGISTERED/CM-CONNECTED and the selected PDU session type is IPv4 or IPv4/IPv6:

3i. Recovery from undetected failure: The AGF will deregister and re-register the FN-RG and reestablish the PDU session OR MAY simply connect the IP session to the existing PDU session.

3ii. Addition of IP Session to existing PDU Session: Connecting the IP session to an existing PDU session applies to the scenario where the PDU session is IPv4v6 and the IP session initiation is for the addition of the IPv4 stack (e.g., the FN-RG initiated IPv6 operation first).

4. This is followed by the forwarding of the DHCPv4 Discover message by the AGF to the 5GC via the established PDU session. The AGF will have set the GIADDR field to the IPv4 address of the AGF as the L3 DHCP relay agent.

5. The 5GC in turn sends a DHCP offer message to the FN-RG via the AN and AGF. This message echoes the GIADDR IP address received from the AGF.

6. The FN-RG will accept the offer with a DHCP request.

7. The 5GC will confirm the DHCP lease with a DHCP ack

8. The FN-RG will then typically resolve the MAC address of the default gateway with an ARP request (where the AGF proxies a reply with its own MAC address) as required in section 6.3.2.1 (L2/L3 Interworking).

8.1.4 FN-RG IP Session Initiation with DHCPv6

Figure 13 shows the call flow for the FN-RG IP session initiation with the AGF initiated by DHCPv6, which subsequently leads to registration and session initiation procedures.

This procedure applies to FN-RGs that are able to start DHCPv6 negotiation without having received a RA with either ‘M’ or ‘O’ ‘flag set to 1. In case the FN-RG does not have this ability, the procedure that applies is the one that requires the FN-RG sending a RS documented in section 8.1.5.

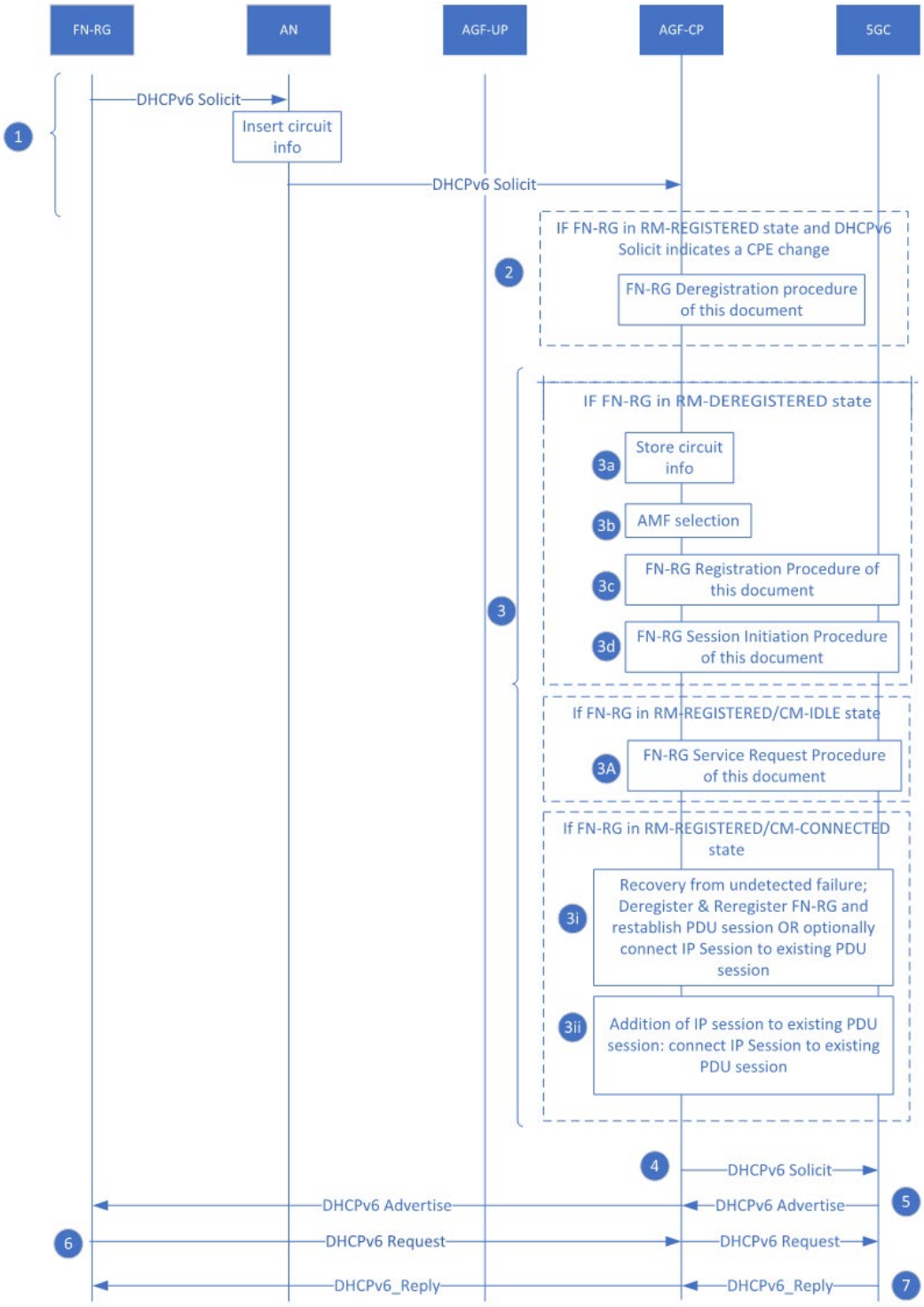


Figure 13: Call flow for FN-RG IP session initiation with DHCPv6

1. The FN-RG sends a DHCPv6 Solicit message to the AGF-CP via the AN based on section iWAN.IPv6 in TR-124.

   The AN receives the DHCPv6 Solicit message. The AN will insert option 18 and/or option 37 'line identification information'. The AN then forwards the entire message to the AGF-CP.

2. On receiving DHCPv6 Solicit message for an FN-RG in the RM-REGISTERED state, AGF-CP checks the DUID within the DHCPv6 message or the RG MAC address. The MAC address may be gleaned from the Ethernet encapsulation or the RGs LLA. If the gleaned information indicates that the FN-RG is different than that recorded for the current registration, the AGF interprets this as an equipment change and executes the AGF-CP initiated FN-RG Deregistration Procedure described in this document before proceeding.

3. The AGF will then handle the IP session initiation according to the current registration and connection state:

   If the state is RM-DEREGISTERED

   3a. The AGF stores the subscriber's information including the FN-RG MAC address, line identification, TCI and port identification metadata.

   3b. The AGF-CP selects an AMF as per step 2 in TS 23.316 [23] subclause 7.2.1.3.

   3c. The FN-RG is registered into the 5GC based on the registration procedure described in section 8.1.6 (based on TS 23.316 [23], clause 7.2.1.3).

   3d. A PDU session is established.

   The AGF establishes a PDU session as defined in section 8.1.8 (based on TS 23.316 [23] clause 7.3.4). The formulation of PDU SESSION ESTABLISHMENT REQUEST by the AGF will adhere to the requirements in section 6.11 (FN-RG IP session initiation requirements).

   The PDU session ID is allocated by the AGF.

   The 5GC, when formulating the reply to PDU SESSION ESTABLISHMENT REQUEST, considers the PDU session type requested by the AGF and the user's subscription data stored in UDM: the latter are authoritative.

   The modifications to procedures for the assignment of LLAs as part of PDU session establishment is as per the requirements in section 6.3.2.1 (L2/L3 Interworking).

   From the PDU SESSION ESTABLISHMENT ACCEPT received by the 5GC the AGF learns the type of PDU session that the subscriber is permitted to: this information is in the Selected PDU Session Type field.

   If the Selected PDU Session Type is IPv6 or IPv4v6, the AGF will act as a DHCP Relay for all the DHCPv6 messages from the FN-RG to 5GC. The SMF is responsible for IPv6 prefix allocation and network parameters.

   Moreover, the AGF will act as an ND Proxy for the FN-RG as documented in the L2/L3 interworking requirements in this document.

   If the PDU SESSION ESTABLISHMENT ACCEPT indicated that FN-RG is not allowed to use IPv6 stack (Selected PDU Session Type=IPv4), the AGF will discard the current DHCPv6 solicit and any further DHCPv6 or ND messages from that FN-RG on the basis of its Line ID, for the duration of the registration.

If the state is RM-REGISTERED/CM-IDLE and the selected PDU session type is IPv6 or IPv4/IPv6:

3A. The AGF performs the Service Request Procedure for FN-RG in this document.

If the state is RM-REGISTERED/CM-CONNECTED and the selected PDU session type is IPv6 or IPv4/IPv6

3i. Recovery from undetected failure: The AGF will deregister and re-register the FN-RG and reestablish the PDU session OR MAY simply connect the IP session to the existing PDU session.

3ii. Addition of IP Session to existing PDU Session: Connecting the IP session to an existing PDU session also applies to the scenario where the PDU session is IPv4v6 and the IP session initiation is for the addition of the IPv6 stack (e.g., the FN-RG initiated IPv4 operation first).

4. The AGF-CP relays the DHCPv6 Solicit message to the 5GC.
5. The 5GC in turn sends a DHCPv6 Advertise Message to the FN-RG via the AN and AGF.
6. The FN-RG responds with a DHCPv6 Request Message.
7. The 5GC confirms the DHCPv6 lease with a DHCPv6 Reply Message.

8.1.5 FN-RG IP Session Initiation with RS followed by DHCPv6

Figure 14 illustrates the scenario when an RS is the first indication of IPv6 IP session initiation. DHCPv6 exchange may follow. This covers the scenarios of SLAAC-only and RA followed by DHCPv6 to either negotiate a delegated prefix (IA_PD) or obtain other attributes such as DNSv6 addresses using DHCPv6 INFORM.

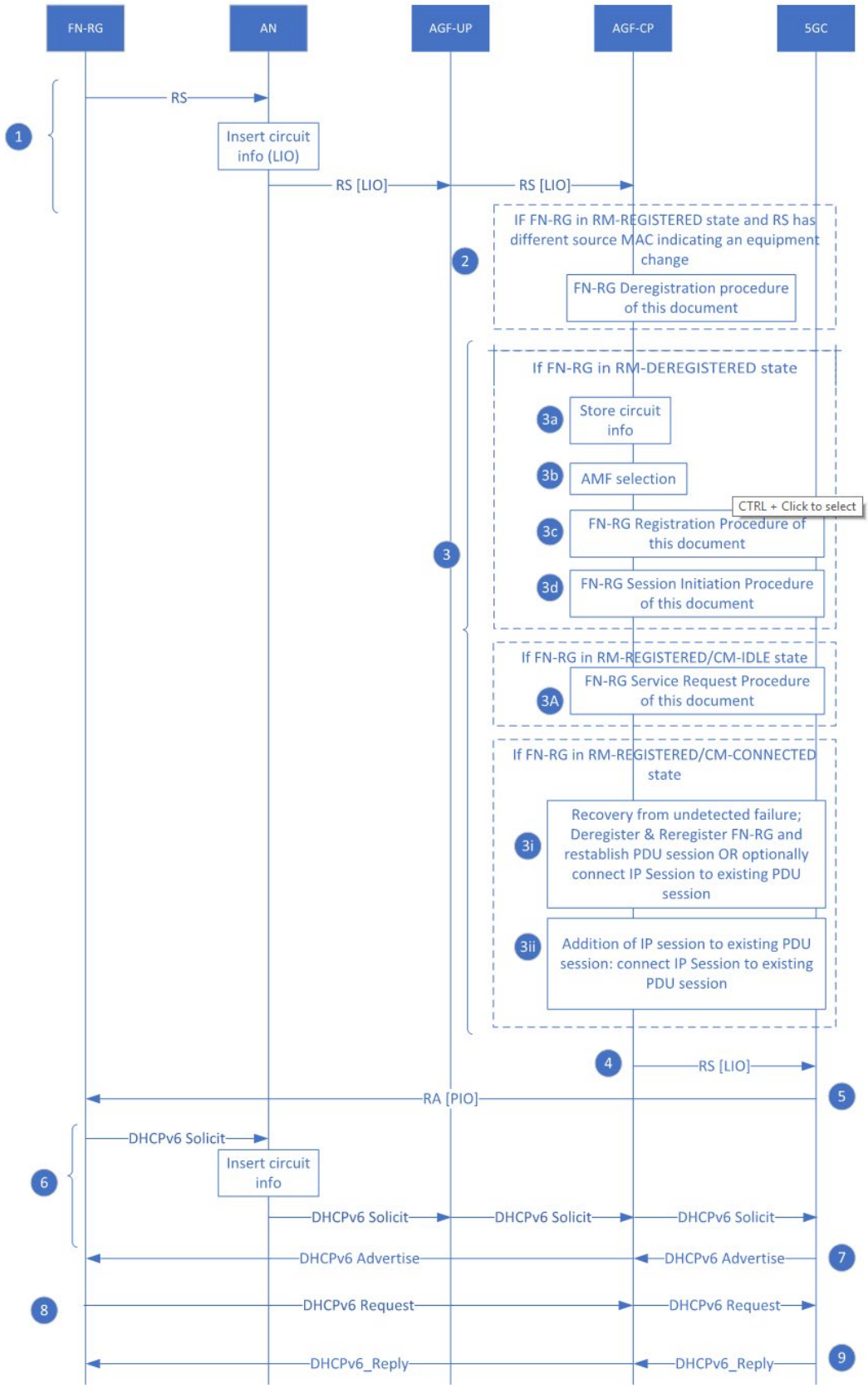


Figure 14: Call flow for FN-RG IP session initiation with SLAAC procedures

1. The FN-RG sends a Router Solicit (RS) message to the AGF-CP via the AN based on section 5.6.2 of TR-146.

   The AN receives the Router Solicit message. It inserts the Line ID option as per Annex 'A' of TR-177 Corrigendum 1 and in turn forwards the entire message to the AGF-CP.

2. On receiving the RS message, if the FN-RG is in the RM-REGISTERED state, the AGF-CP checks the RG MAC address. This may be gleaned from the Ethernet header or RG's LLA. If the gleaned information indicates that the FN-RG is different than that recorded for the current registration, the AGF interprets this as an equipment change and executes the AGF-CP initiated FN-RG Deregistration Procedure described in this document before proceeding.

3. The AGF will then handle the IP session initiation according to the current registration and connection state:

   If the state is RM-DEREGISTERED

   3a. The AGF stores the subscriber's information including the FN-RG MAC address, line identification, TCI, and port identification metadata.

   3b. The AGF-CP selects an AMF as per step 2 in TS 23.316 [23] subclause 7.2.1.3.

   3c. The FN-RG is registered into the 5GC based on the registration procedure described in section 8.1.6 (based on TS 23.316 [23], clause 7.2.1.3).

   3d. A PDU session is established.

   The AGF establishes a PDU session as defined in section 8.1.8 (based on TS 23.316 [23] clause 7.3.4). The formulation of PDU SESSION ESTABLISHMENT REQUEST by the AGF will adhere to the requirements in 6.11 (FN-RG IP session initiation requirements).

   The PDU session ID is allocated by the AGF.

   The 5GC, when formulating the reply to PDU SESSION ESTABLISHMENT REQUEST, considers the PDU session type requested by the AGF and the user's subscription data stored in UDM: the latter are authoritative.

   The modifications to procedures for the assignment of LLAs as part of PDU session establishment is as per the requirements in section 6.3.2.1 (L2/L3 Interworking).

   From the PDU SESSION ESTABLISHMENT ACCEPT received by the 5GC the AGF learns the type of PDU session that the subscriber is permitted to: this information is in the Selected PDU Session Type field.

   If the Selected PDU Session Type is IPv6 or IPv4/v6, the AGF will relay the RS message from the FN-RG to the 5GC. The SMF is responsible for prefix allocation and network parameters.

   Moreover, the AGF will act as an ND Proxy for the FN-RG as documented in the L2/L3 interworking requirements in this document.

   If the PDU SESSION ESTABLISHMENT ACCEPT indicated that FN-RG is not allowed to use IPv6 stack (Selected PDU Session Type=IPv4), the AGF will discard the current RS and any further DHCPv6 or ND messages from that FN-RG on the basis of its Line ID.

If the state is RM-REGISTERED/CM-IDLE and the selected PDU session type is IPv6 or IPv4/IPv6

3A. The AGF performs the Service Request Procedure for FN-RG in this document.

If the state is RM-REGISTERED/CM-CONNECTED and the selected PDU session type is IPv6 or IPv4/IPv6

3i. Recovery from undetected failure: The AGF will deregister and re-register the FN-RG and reestablish the PDU session OR MAY simply connect the IP session to the existing PDU session.

3ii. Addition of IP Session to existing PDU Session: Connecting the IP session to an existing PDU session applies to the scenario where the PDU session is IPv4v6 and the IP session initiation is for the addition of the IPv6 stack (e.g., the FN-RG initiated IPv4 operation first).

4. The AGF-CP relays the RS to the 5GC, removing the Source Link Layer Address option, if present.

5. The 5GC sends a router advertisement (RA) to the FN-RG. This may (as a consequence of local configuration) include a prefix information option (PIO). For N:1 VLAN, the AGF when forwarding the RA uses the unicast MAC address of the FN-RG (refer to section 6.2.6 of RFC 4861 [47]). The AGF forwards the RA towards the FN-RG making sure to insert, if missing, or rewrite, if present, the Source Link Layer Address option.

6. The FN-RG sends a DHCPv6 Solicit message to the AGF-UP via the AN. The AN will insert option 18 and/or option 37 line identification information (this will only be of further significance for N:1 VLAN support). If a received RA did not contain a prefix information option, the DHCPv6 Solicit asks for both IA_NA and IA_PD. If the received RA did contain a prefix information option, the DHCPv6 Solicit asks for IA_PD only. The AGF receives the DHCPv6 Solicit and by the Line-Id or by the VLAN it recognizes as coming from an FN-RG already mapped to a PDU session supporting IPv6. Therefore it will simply relay the DHCPv6 message to the 5GC.

7. The 5GC in turn sends a DHCPv6 Advertise Message to the FN-RG via the AN and AGF.

8. The FN-RG responds with a DHCPv6 Request Message.

9. The 5GC confirms the DHCP lease with a DHCPv6 Reply Message.

Note: Steps from 6 to 9 may or may not occur, depending on the FN-RG behavior.

8.1.6 Registration Management Procedure for FN-RG

Figure 15 shows the call flow for the registration management of an FN-RG. Since FN-RG is a legacy device that does not support N1, the AGF handles NAS signaling on behalf of the FN-RG.

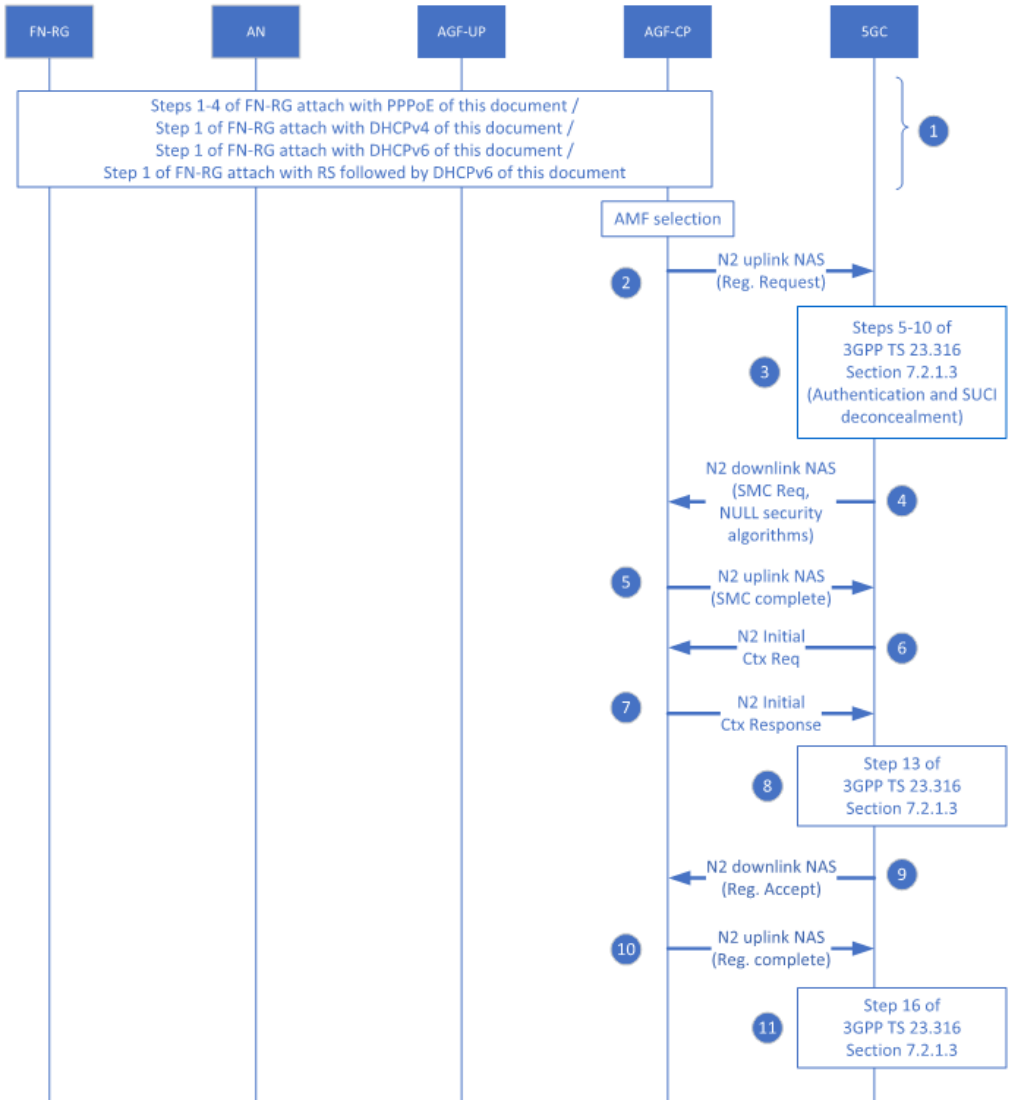


Figure 15: Call flow for the Registration Management Procedure for an FN-RG

1. In order to carry out the registration procedure, it is a pre-requisite that a connection exists between the FN-RG and AGF-CP via PPPoE, DHCP or SLAAC using one of:

    a. Steps 1-4 of FN-RG IP session initiation with PPPoE (Section 8.1.1)

    b. Steps 1-9 of FN-RG IP session initiation using L2TP (Section 8.1.2)

    c. Step 1 of FN-RG IP session initiation with DHCPv4 (Section 8.1.3)

    d. Step 1 of FN-RG IP session initiation with DHCPv6 (Section 8.1.4)

    e. FN-RG IP session initiation with RS followed by DHCPv6 (Section 8.1.5).

    After authentication, the AGF-CP selects an AMF based on the AN parameters and local policy.

2. The AGF-CP constructs a registration request to be forwarded to the 5GC on behalf of the FN-RG as specified in step 3 of TS 23.316 [23] subclause 7.2.1.3. As per step 3 of TS 23.316 [23] subclause 7.2.1.3, this registration request contains an authentication indication for the 5GC indicating that the FN-RG has been authenticated by the AN.
3. The next steps involve authentication by the 5GC which includes AUSF selection and SUCI concealment in the 5GC as per steps 4-9 in TS 23.316 [23] subclause 7.2.1.3.
4. On successful authentication by the 5GC, the 5GC initiates a NAS Security Mode Command procedure towards the AGF-CP based on step 10a of TS 23.316 [23] figure 7.2.1.3-1. The SMC request has NAS security algorithms - integrity protection algorithm and ciphering algorithm set to NULL.
5. The AGF-CP responds with a NAS Security Mode Complete message and a NAS security context is created between the AGF and 5GC.
6. The 5GC next sends an N2 Initial Context Setup Request message to the AGF-CP. This may include the RG Level Wireline Access Characteristics.
7. The FN-RG context is created and is indicated by the AGF-CP to the 5GC via the Initial Context Setup Response.
8. The 5GC performs step 13 as in TS 23.316 [23] figure 7.2.1.3-1.
9. The 5GC sends a NAS Registration Accept message to the AGF-CP.
10. The AGF-CP responds with a NAS Registration Complete message.
11. 5GC performs step 15 as in TS 23.316 [23] subclause 7.2.1.3.

8.1.7 Service Request Procedure for FN-RG

The Service Request Procedure described below is initiated by the AGF-CP when the state of the FN-RG on the AGF is (CM-IDLE, RM-REGISTERED).

> **Note:** The service request procedures may also be valid when the FN-RG is in the CM-CONNECTED case. This document does not address this use case.

The procedure is as per clause 7.2.2.2 of TS 23.316 [23] with the following details:

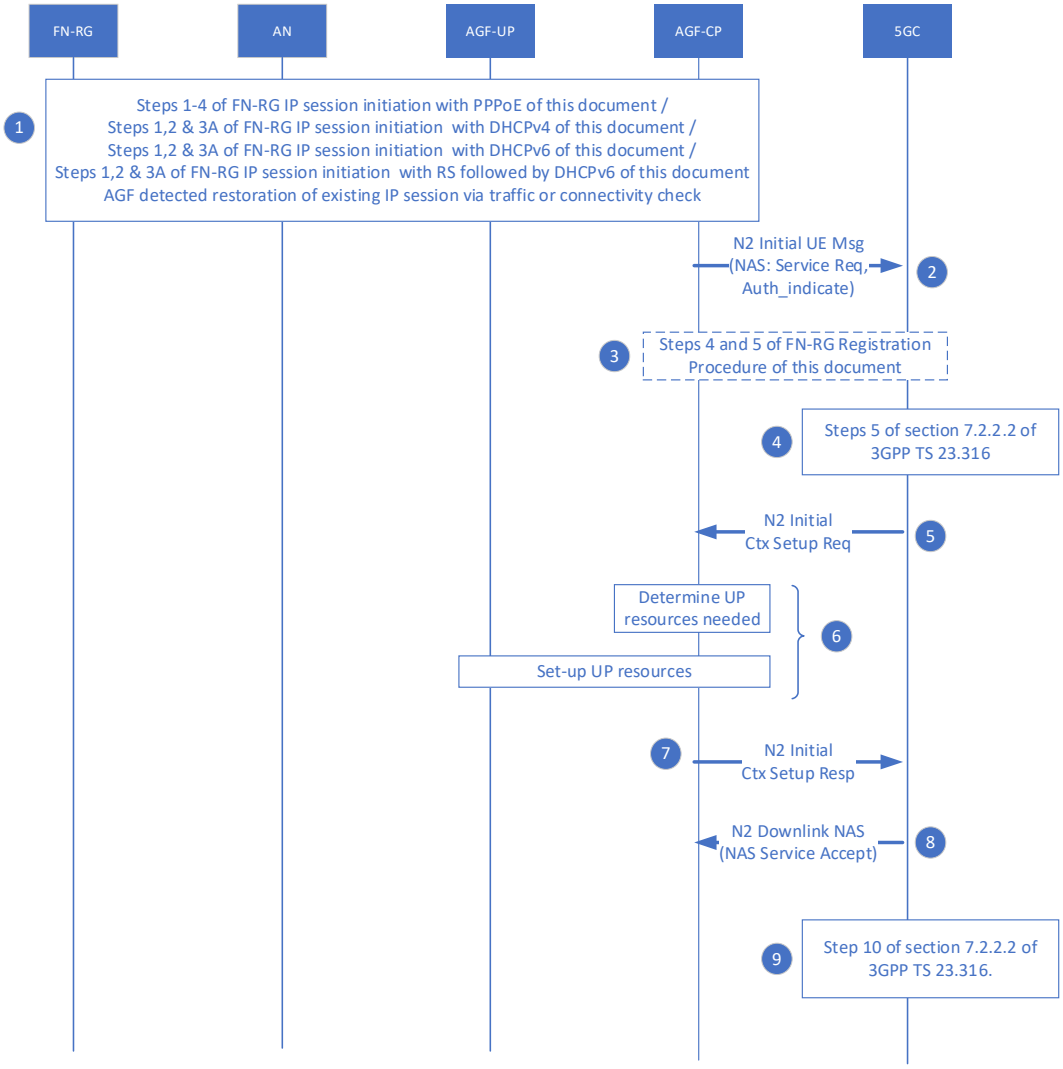


Figure 16: FN-RG Service Request Procedure via W-5GAN

1. The FN-RG connects to the AGF-CP via PPPoE, DHCP or SLAAC using one of:

    a. Steps 1-4 of FN-RG IP session initiation with PPPoE (Section 8.1.1)

    b. Steps 1-9 of FN-RG IP session initiation using L2TP (Section 8.1.2)

    c. Step 1 of FN-RG IP session initiation with DHCPv4 (Section 8.1.3)

    d. Step 1 of FN-RG IP session initiation with DHCPv6 (Section 8.1.4)

    e. FN-RG IP session initiation with RS followed by DHCPv6 (Section 8.1.5).

    OR the FN-RG has not detected the outage and resumes using the existing IP session

    The AGF detects a resumption in connectivity via the reception of well formed traffic on an existing IPv4oE or IPv6OE session.

2. The AGF-CP sends the AN parameters and a Service Request message on behalf of FN-RG within an N2 Initial UE message as per step 3 of clause 7.2.2.2 of TS 23.316 [23].

3. The 5GC may initiate the security mode command procedure as per steps 4 and 5 of section 8.1.6.

   After successful establishment of the signaling connection, the AGF-CP and the 5GC can exchange NAS signaling

4. Step 5 of clause 7.2.2.2 in TS 23.316 [23] is executed in the 5GC.

5. The 5GC sends a N2 UE Initial Context Setup Request message as per step 6 of clause 7.2.2.2 of TS 23.316 [23] which contains the N2 SM information received from SMF(s), RG Level Wireline Access Characteristics, and other parameters intended for the FN-RG. All the parameters received from the 5GC in this step may not be applicable for AGF and can be left for implementation. The parameters in the INITIAL CONTEXT SETUP REQUEST, as defined in clause 5.3 of TS 29.413 [18], are not applicable to this step.

   Note: This single message can setup the UP for several PDU sessions, but this is FFS.

6. The AGF-CP determines the UP resources and sets-up the UP resources together with the AGF-UP. This corresponds to step 7 of clause 7.2.2.2 of TS 23.316 [23].

7. After setting up the UP resources, the AGF-CP sends a N2 Initial Context Setup Response to the 5GC as per step 8 of clause 7.2.2.2 of TS 23.316 [23].

8. The 5GC sends a NAS Service Accept message to the AGF-CP as per step 9 of clause 7.2.2.2 of TS 23.316 [23].

9. Further steps are executed in 5GC as per step 10 of clause 7.2.2.2 of TS 23.316 [23] .

8.1.8 Session Initiation Procedure for FN-RG

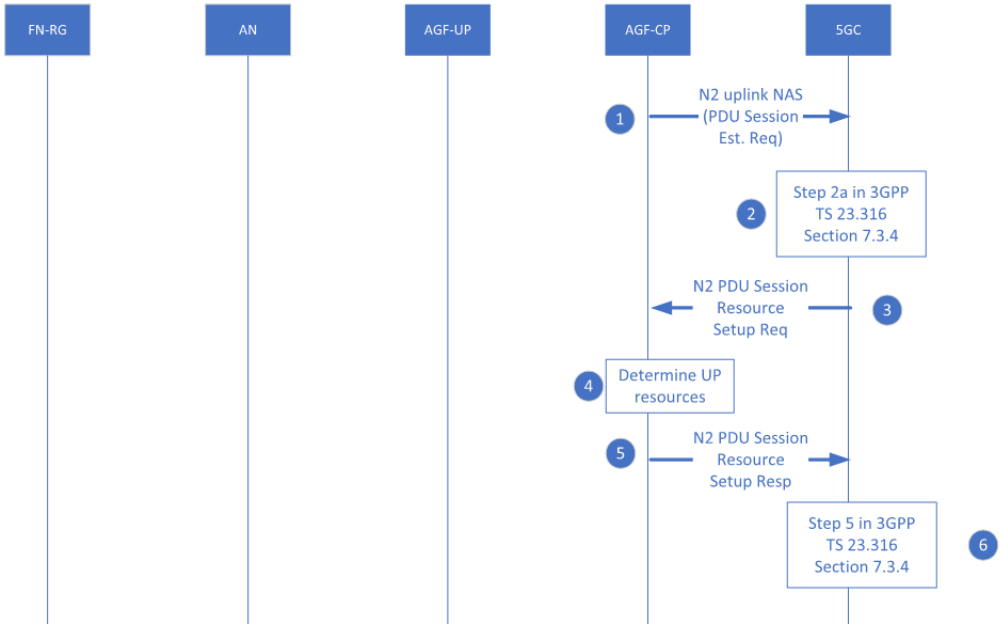


Figure 17: Call flow for the PDU Session Initiation Procedure for an FN-RG

1. The AGF-CP is triggered to send an N2 uplink NAS message with a PDU Session Establishment Request to the 5GC. The session request formulation adheres to the requirements documented in section 6.11 (FN-RG IP session initiation requirements)

2. The 5GC performs step 2a of TS 23.316 [23] clause 7.3.4.

3. The 5GC sends a N2 PDU Session Resource Setup Request to the AGF-CP as step 2b of TS 23.316 [23] clause 7.3.4.

4. This N2 PDU Session Resource Setup Request is used by the AGF to assign UP resources in the AN based on the AN specific subscription information in the RG-LWAC which describes the resource model for the circuit serving the FN-RG.

5. The AGF responds to the 5GC with a N2 PDU Session Resource Setup Response.

6. The 5GC performs step 5 as in TS 23.316 [23] clause 7.3.4 (step 6a of Figure 17).

8.1.9 Deregistration Procedure for FN-RG

Figure 18 shows the call flow for the deregistration of an FN-RG from the 5GC. The deregistration procedure can either be AGF-CP initiated or 5GC-initiated.

The triggers for UE initiated deregistration may include:

- Detecting a change of FN-RG equipment since the last registration, e.g., shown by a new MAC address in the signaling packets initiating a new IP session.

- Detecting a 5G-RG attempting to register on the same Line ID (migration scenario).

- The termination of the PPPoE based IP session by the FN-RG

- Receipt of a DHCPv4 Release for a PDU session type IPv4.

- Receipt of a DHCPv6 Release for a PDU session type IPv6.

- Receipt of both a DHCPv4 Release and DHCPv6 release for a PDU session type IPv4v6.

The triggers for network initiated deregistration include:

- Termination of the subscription in 5GC, e.g., triggered by non-payment.

- The expiration of the AMF deregistration timer.

  Note: If the state of FN-RG in the AMF is CM-IDLE and the deregistration timer initiated upon the transition to CM-IDLE expires, then the 5GC or AMF simply considers the FN-RG to be deregistered and no explicit signaling occurs among the network nodes. This can be considered as network-initiated deregistration which does not involve any message exchanges between the AMF and the AGF. However, if the loss of connectivity to the FN-RG is kept local to AGF-CP until a specified outage duration is exceeded, then this can be UE-initiated deregistration initiated by the NAS proxy in the AGF.

  Note: An implementation may choose to employ “strategic hiding” of UE initiated deregistration. This does not apply to detection of a 5G-RG (migration scenario) and detection of a change of FN-RG equipment.

This procedure is similar to the 5G-RG deregistration procedure described in section 8.2.5 (Deregistration Procedure for 5G-RG), with the difference that the AGF-CP acts on behalf of an FN-RG as an endpoint for N1 NAS signaling.

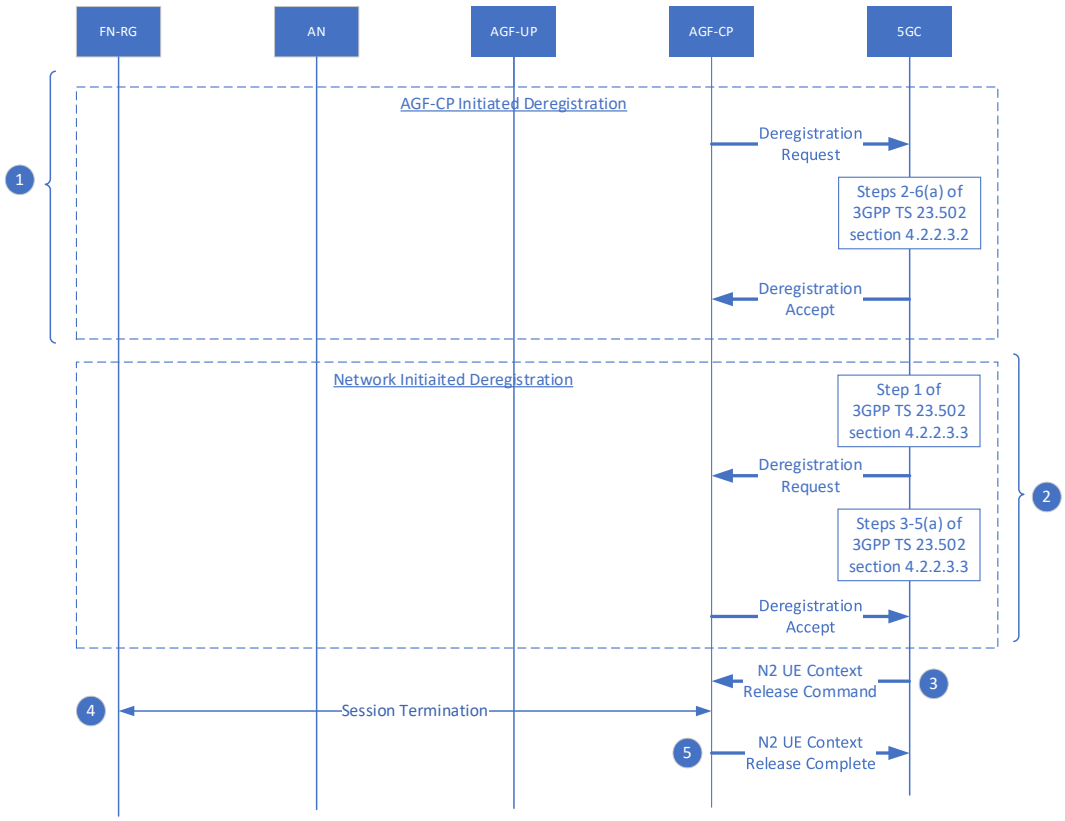


Figure 18: Call flow for Deregistration Procedure for FN-RG

1. The deregistration procedure for the FN-RG can be initiated by the AGF-CP on behalf of FN-RG and is triggered by one of the events described at the beginning of this section. The deregistration is specified in clause 7.2.1.4 in TS 23.316 [23], which is in turn based on UE-initiated deregistration procedure in TS 23.502 [27], clause 4.2.2.3.2.

   Note: Scenarios where the DHCP lease does not fate share with the PDU session are FFS.

   The AGF-CP sends a deregistration request towards the 5GC on behalf of the FN-RG. This is followed by session release and policy termination mechanisms in 5GC. The 5GC then sends a deregistration accept message which is terminated at the AGF-CP.

   De-Registration Request will release all the PDU Sessions associated with the RG and release the N2 UE context. This can be preceded by PDU Session Release Procedure in case the N2 UE context needs to be retained.

2. The 5GC can also initiate the deregistration procedure towards the FN-RG which is specified in clause 7.2.1.4 in TS 23.316 [23], which is in turn based on section Network-initiated deregistration procedure in clause 4.2.2.3.3 of TS 23.502 [27].

   The AGF-CP sends a deregistration accept message to the 5GC on behalf of the FN-RG.

3. The 5GC next sends a N2 UE Context Release Command to the AGF-CP as in step 3 of section 8.2.5 (or step 2 of clause 7.2.1.2 in TS 23.316 [23]).

4. The AGF-CP uses an LCP Terminate Request followed by a PPPoE PADT to terminate any active PPPoE session with the FN-RG in line with step 4 of section 8.2.5 (or step 3 of clause 7.2.1.2 in TS 23.316 [23]). For DHCP FN-RG, DHCP Force Renew can be used where the FN-RG Supports it and Reject the Renew Request.

5. After terminating active PPPoE session with the FN-RG, the AGF-CP sends a N2 UE Context Release Command message to the 5GC as in step 4 of clause 7.2.1.2 in TS 23.316 [23].

Note: Steps 4 and 5 only apply to PPPoE based IP sessions. Communicating IP session termination for IPoE is FFS.

8.1.10 FN-RG or Network Requested PDU Session Modification via W-5GAN

PDU session modification cannot be supported by a FN-RG. Any trigger such as subscription change will not take place until a new PDU session is established.

The Network Requested PDU Session Modification can be initiated by the SMF, possibly triggered due to a subscription change. There does not appear to be an actual use case where an FN-RG can do anything to trigger an AGF action, it is included here for completeness.

This procedure is as per clause 7.3.6 of TS 23.316 [23], which is in turn referring to clause 7.3.2 of TS 23.316 [23]. Applicable use cases and wireline specific clarifications are FFS.

8.1.11 FN-RG or Network Requested PDU Session Release via W-5GAN

The PDU session release procedure is triggered by:

- DHCP lease expiry for IPoE, (**Note:** The relationship between DHCP lease management and PDU session management is FFS)
- graceful shutdown of a PPP session by the FN-RG
- or receipt of a PADT for PPPoE from the FN-RG

  Note: both graceful shutdown of a PPP session or a PADT received by the FN-RG trigger the FN-RG Deregistration as per section 8.1.10.
- 5GC action

This procedure is as per clause 7.3.7 of TS 23.316 [23], which is in turn referring to clause 7.3.3 with the following clarifications:

1. For initiating this procedure, it is a prerequisite that connectivity exists between the FN-RG and AGF-CP and has at least one IP session mapped to a PDU session established between the AGF and UPF as per step 1 of clause 7.3.3 of TS 23.316 [23].

   The AGF-CP creates a PDU Session Release Request towards the 5GC on behalf of FN-RG as per bullet 3 in clause 7.3.7 in TS 23.316 [23].
2. The 5GC executes step 3 as in clause 7.3.3 in TS 23.316 [23].
3. The AGF-CP receives N2 Resource Release Request from 5GC as per step 4 of clause 7.3.3 in TS 23.316 [23].
4. Upon receiving the N2 Release Request message, the AGF-CP triggers the release of the corresponding UP resources as per bullet 4 of clause 7.3.7 in TS 23.316 [23].

   If the PDU Session Release is network requested, and the session is PPPoE based, the AGF-CP sends a PADT to the FN-RG to terminate the IP session. If the session is IPoE based, then the AGF will release the user plane resources regardless of the inability to inform the FN-RG of this release.
5. The AGF-CP sends a N2 Release Ack towards the 5GC as per step 6 of clause 7.3.3 in TS 23.316 [23].
6. Step 7 is executed in 5GC as per clause 7.3.3 in TS 23.316 [23].

7. The AGF-CP directly creates an Uplink NAS Transport Message towards the 5GC, which contains the PDU Session Release Ack as per bullet 5 in clause 7.3.7 in TS 23.316 [23].

8. Step 11 is executed in 5GC as per clause 7.3.3 in TS 23.316 [23].

8.1.12 FN-RG AN Release via W-5GAN

The AN Release Procedure for the FN-RG is used to release the NG-AP signaling connection and the associated N3 user plane connections between the W-5GAN and the 5GC.

The AN release procedure is triggered by a loss of connectivity with the FN-RG detected by the AGF. It is started by the AGF with a N2 UE Context Release Request to the AMF. Upon receiving the N2 UE Context Release command as a reply from the AMF, the AGF flushes the FN-RG N2 context, the N3 resources and the IP session resources, retaining the N1 context as proxy UE. Besides that, the AGF starts a local non-3GPP Implicit Deregistration timer using the default value or the value received from by the AMF in the in NAS Registration Accept message (as documented in TS 24.501 [11] clause 8.2.7.17). The N1 context related to the FN-RG is retained by the AGF as proxy UE until the non-3GPP Implicit Deregistration timer expires.

The AN Release procedure is as per clause 7.2.5.3 of TS 23.316 [23], which is in turn referring to clause 7.2.5.2 with the following clarifications:

1. It is a prerequisite that the FN-RG is registered into the 5GC. The AGF may have a PDU session established on behalf of the FN-RG as per step 1 of clause 7.2.5.2 in TS 23.316 [23].

   The AGF-CP detects that the FN-RG is unreachable, which serves as the trigger for initiating this procedure as per step 2 in clause 7.2.5.2 in TS 23.316 [23]. This may be via liveness detection means (e.g., LCP Echo Requests).

2. The AGF-CP sends a N2 UE Context Release Request to 5GC as per step 3 of clause 7.2.5.2 in TS 23.316 [23].

3. The AGF-CP receives a N2 UE Context Release Command from the 5GC as per step 4 of clause 7.2.5.2 in TS 23.316 [23].

4. The AGF-CP initiates the release of the IP session local resources as per bullet 2 of clause 7.2.5.3 in TS 23.316 [23]. The release process is entirely a local action and involves the release of state and scheduler appearances at the AGF.

5. The AGF-CP next sends a N2 UE Context Release Complete to the 5GC as per step 6 of clause 7.2.5.2 in TS 23.316 [23].

6. This is followed by PDU session user plane deactivation in the 5GC as per step 7 of clause 7.2.5.2 in TS 23.316 [23].

8.1.13 Configuration Update Procedure for FN-RG

This procedure is used by the network to update the FN-RG configuration which consists of:

- Access and mobility management related parameters provided by the AMF.

- FN-RG related Policy provided by the PCF. The use of URSP to determine PDU session type, DNN and NSSAI is FFS.

This procedure is similar to the 5G-RG configuration update procedure described in clause 8.2.10 and also described in clause of 7.2.3.2 of TS 23.316 [23], with the difference that the AGF-CP acts on behalf of the FN-RG as an endpoint for N1 NAS signaling.

8.1.13.1 FN-RG Configuration Update procedure for Access and Mobility Management related parameters

This procedure can be further elaborated below based on clause 7.2.3.2 of TS 23.316 [23], which is in turn based on clause 4.2.4.2 of TS 23.502 [27]:

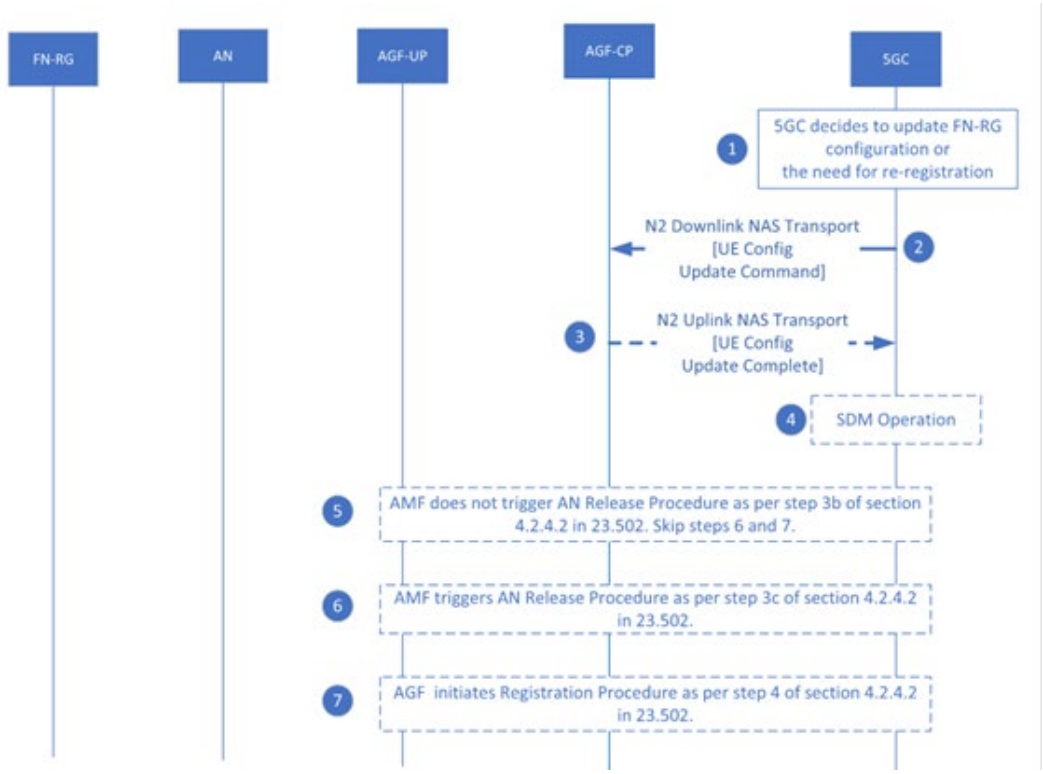


Figure 19: FN-RG Configuration Update Procedure for access and mobility management related parameters via W-5GAN

1. The 5GC determines the need for FN-RG configuration update or re-registration procedure as per step 0 of clause 4.2.4.2 in TS 23.502 [27]. One of the triggers for initiating this procedure is the reception of subscriber data update notification from the UDM and the RG-LWAC parameter can be updated through this procedure.

   If the FN-RG state stored in the AGF-CP is CM-IDLE, the 5GC waits until this changes to CM-CONNECTED state as Network Triggered Service Request is not applicable in this scenario.

2. The 5GC sends a UE Configuration Update command in an N2 Downlink NAS Transport message to the FN-RG which terminates at the AGF-CP with one or more parameters as per step 1 of clause 4.2.4.2 in TS 23.502 [27].

   Note: Refer to subclause 8.2.19 in TS 24.501 [11] for more details on IEs (Information Elements) for the message “Configuration Update Command” and subclause 9.2.5.2 of TS 38.413 [16] for IEs on “Downlink NAS Transport” message.

3. If applicable, the AGF-CP sends an acknowledgement on behalf of the FN-RG for the UE Configuration Update Indication via the UE Configuration Update Complete in an N2 Uplink NAS Transport message as per step 2a of clause 4.2.4.2 in TS 23.502 [27].

4. The 5GC may also perform an SDM operation to indicate to the UDM that the AGF-CP (on behalf of FN-RG) has received the subscription change indication as per step 2b of clause 4.2.4.2 in TS 23.502 [27].

5. If the existing connectivity to the network slices is not affected with the new parameters sent to the AGF-CP, the 5GC does not release the NAS signaling connection for the AGF-CP after receiving the acknowledgement in step 3 above and no immediate registration is required, as per step 3b of clause 4.2.4.2 in TS 23.502 [27].

6. If the existing connectivity to the network slices is affected due to the update with new parameters, the 5GC in its UE Configuration Update Command message includes the new network slice information as per step 3c of clause 4.2.4.2 in TS 23.502 [27].

   If the 5GC cannot provide the new network slice information, it sends an indication to the AGF-CP to initiate the registration procedure. After receiving the acknowledgement in step 3 above, the 5GC releases the NAS signaling connection for the AGF-CP as per step 3c of clause 4.2.4.2 in TS 23.502 [27].

7. The AGF-CP, on behalf of the FN-RG initiates the registration procedure after it enters the CM-IDLE state as per step 4 of clause 4.2.4.2 in TS 23.502 [27].

8.1.13.2 FN-RG Configuration Update procedure for transparent FN-RG Policy delivery

This procedure is initiated by the 5GC (or PCF) to change or provide new FN-RG policies in the AGF-CP. This is as per clause 7.2.3.2 in TS 23.316 [23], which is in turn based on clause 4.2.4.3 in TS 23.502 [27]:

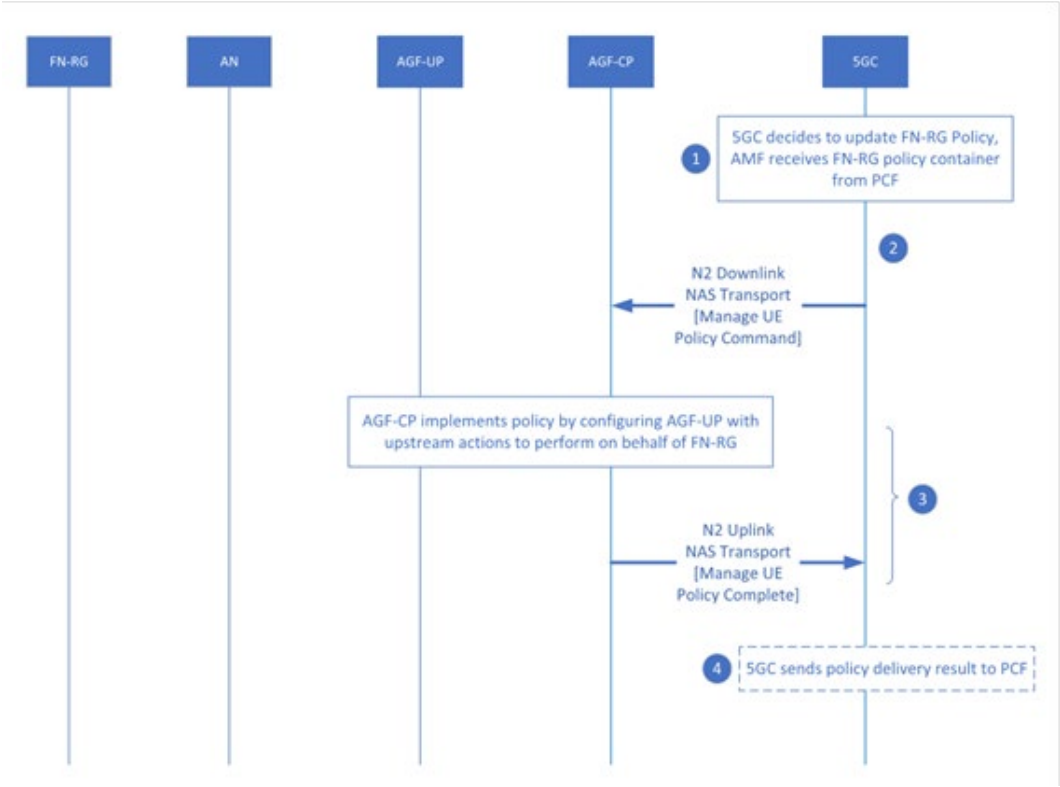


Figure 20: FN-RG Configuration Update Procedure for transparent UE policy delivery via W-5GAN

1. The 5GC (or PCF) decides to update the FN-RG policies based on the triggering conditions as per step 0 clause 4.2.4.3 of TS 23.502 [27]. The AMF (in the 5GC) receives the UE policy container from the policy function as per step 1 of clause 4.2.4.3 of TS 23.502 [27].
2. The AGF-CP receives the FN-RG policy from the 5GC in an N2 Downlink NAS Transport message as per step 3 of clause 4.2.4.3 of TS 23.502 [27] containing the Manage UE Policy Command.

   Note: The IE "Payload Container Type" is set to "UE Policy Container" as per TS 24.501 [11] subclause 8.2.11 and annex D.
3. The AGF-CP updates the policy provided by the 5GC for the FN-RG and sends the result to the 5GC in an N2 Uplink NAS Transport message as per step 4 of clause 4.2.4.3 of TS 23.502 [27] which contains the Manage UE Policy Complete message. In this issue of the specification, the AGF ignores the UE policy rules, but sends a positive result.

   Note: There is no signaling or message exchanges involved between the AGF and FN-RG for this procedure.
4. The AMF (in the 5GC) sends this response from the AGF-CP to the 5GC policy function (PCF) as per step 5 of clause 4.2.4.3 of TS 23.502 [27].

8.2 For a 5G-RG

8.2.1 Registration Management Procedure for 5G-RG

Figure 21 shows the call flow for the registration management of a 5G-RG. It utilizes PPPoE to start 3GPP NAS registration with the 5GC. During Registration procedure the 3GPP NAS between the 5G-RG and the AGF is encapsulated in EAP-5G protocol. The EAP-5G is a vendor-specific EAP method (EAP-5G) which is defined in TS 24.502 [12] utilizing the "Expanded" EAP type and the existing 3GPP Vendor-Id registered with IANA under the SMI Private Enterprise Code registry (i.e., 10415). The EAP-5G method is not utilized for performing the authentication but only for encapsulating the NAS messages. The AN parameters are sent by 5G-RG during registration procedure in EAP-5G message as defined in TS 24.502 [12].

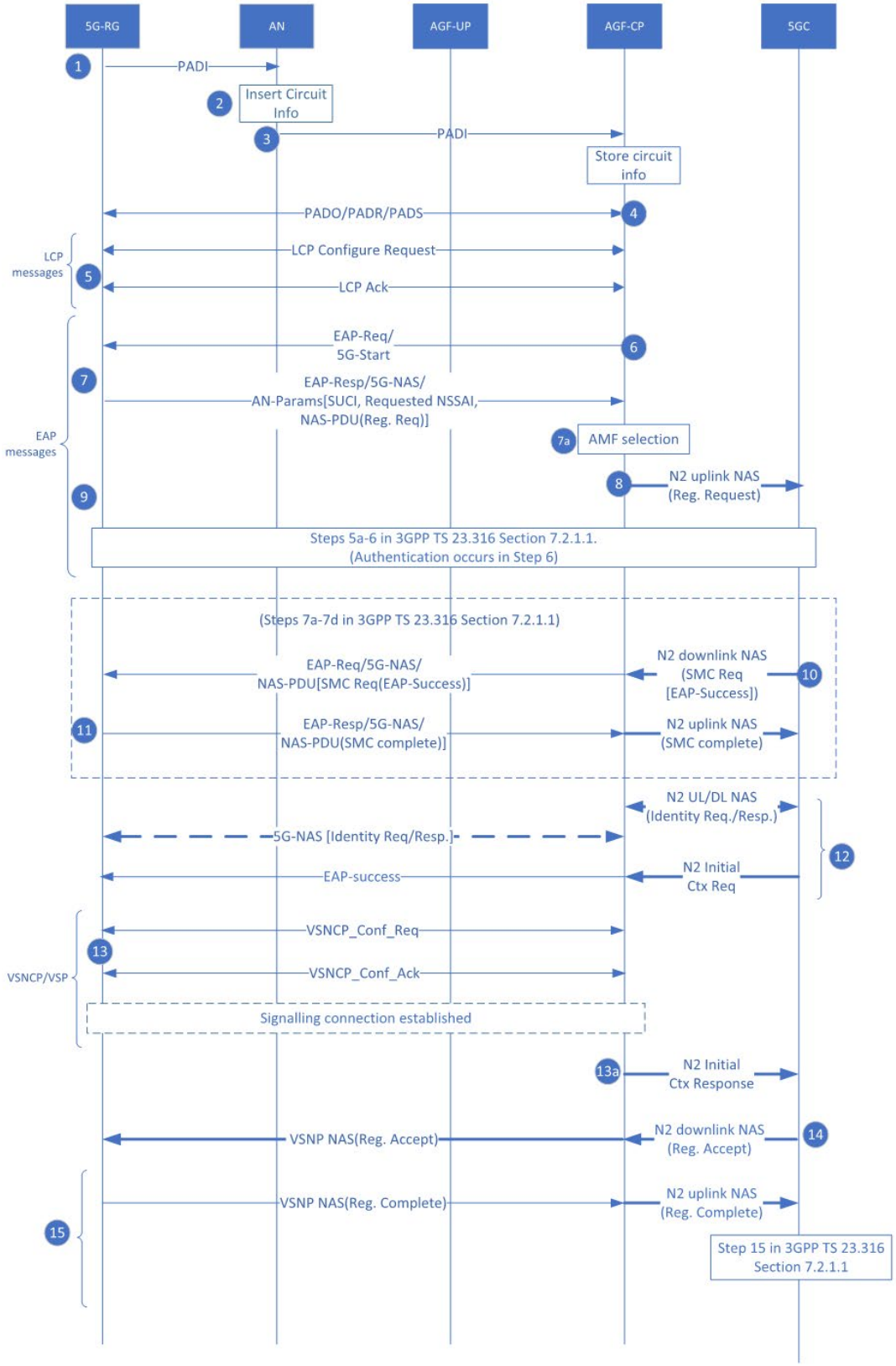


Figure 21: Call flow for the registration management procedure for a 5G RG

1. The 5G-RG starts a PPPoE session with a PADI message.

2. The AN receives the PPPoE PADI message and inserts PPPoE Tags into the PADI message. The PPPoE tags include PPPoE Circuit and Remote ID. The access node will insert vendor specific: 0x0de9 (IANA administered ADSL forum) option 0x01 “circuit-id” and option 0x02 “remote-id” information. This is required for authentication and also serves as a location information for the 5GC.

3. The AN then forwards the entire message to the AGF-CP.

4. Once the AGF-CP receives the PADI message, the AGF-CP will store the subscriber’s information based on both the Ethernet header and PPPoE tags. The 5G-RG will complete the PPPoE discovery process as outlined in section 5 in RFC 2516 [39]. After receiving the PADR message, the AGF-CP will allocate Session ID and send it to the 5G-RG via a PADS message. The Session ID will be used as the PPP encapsulation for the following LCP, EAP, VSNCP procedures between the 5G-RG and the AGF-CP to carry the 5G NAS signaling. The AGF-CP will store the Session ID into the 5G-RG context.

5. After the PPPoE discovery process completes, both the AGF-CP and 5G-RG establish the link layer with LCP packet message exchanges as described in section 5 of RFC 1661 [40].

   The LCP Configure-Request and Configure-Ack messages are exchanged between the 5G-RG and AGF-CP via the AN.

   For the 5G-RG, in addition to any other configuration options, the LCP ‘configure-request’ message must include the BBF defined Vendor Specific Option (VSO) using the ADSL forum IEEE administered OUI 0x256d as per RFC 2153 [36]:

   - RG type=5G-RG, this is to allow the AGF to recognize a 5G-RG and serve it accordingly. This is also to allow the 5G-RG to become aware of the PPP server capabilities and possibly downgrade to FN-RG upon receiving a Reject as response of the LCP Configuration-Request. If the 5G-RG cannot downgrade, LCP will fail to negotiate and stop at this stage.

   For the AGF-CP, the LCP ‘configure-request’ message includes a new BBF defined VSO (which is the same option the 5G-RG will provide in its LCP Configure-Request):

   - Authentication-Protocol option method = EAP (0xC227)

   The AGF-CP will complete the LCP procedure by sending a Configure-Ack to the 5G-RG as specified in section 5.2 of RFC 1661 [40].

6. The AGF-CP will send an EAP-Request/5G-Start packet to the 5G-RG to initiate an EAP-5G session as per step 2 of TS 23.316 [23] clause 7.2.1.1. The 5G-RG acknowledges start of the EAP-5G session by sending an EAP-Response/5G-NAS message as per step 3 of TS 23.316 [23] clause 7.2.1.1 which includes:

   - A NAS-PDU field containing the NAS message (i.e., Registration Request) initiated by the 5G-RG; and
   - An AN-parameters field containing the access network parameters, GUAMI, if available, selected PLMN, NSSAI, establishment cause, etc.

   Note: although PLMN selection is not supported for W-5GAN access, the 5G-RG still provides a selected PLMN ID in the AN parameters within the EAP-Response/5G-NAS message to the AGF as per note 3 in step 3 of clause 7.2.1.1 in TS 23.316 [23].

Further NAS messages between the 5G-RG and the AMF, via the AGF-CP, must be inserted in the NAS-PDU field of an EAP-Response/5G-NAS (5G-RG to AGF-CP direction) and EAP-Request/5G-NAS (AGF-CP to 5G-RG direction) message

The following EAP messages are encapsulated in PPP.

7. The AGF-CP, on reception of the AN-parameters in EAP-Response/5G-NAS, MUST execute the AMF selection as per step 4 of TS 23.316 [23] clause 7.2.1.1.

8. The AGF-CP, on reception of the NAS-PDU in EAP-Response/5G-NAS, must forward the NAS message (Registration Request) to the selected AMF by sending an 'INITIAL UE MESSAGE' as specified in TS38.413 [16] Clause 8.6.

   The AGF-CP MUST forward the Registration Request received from the 5G-RG within an N2 initial UE message (NAS message, Line ID based ULI, Establishment cause, UE context request, selected PLMN ID) as per step 4 of TS 23.316 [23] clause 7.2.1.1.

   A unique RAN UE NGAP ID (identifier of RG level N2 interface, which is similar with RAN UE NGAP ID) will be allocated by the AGF-CP to be used for the 5G-RG and the AGF-CP must include this identity in the 'INITIAL UE MESSAGE'.

   In addition, the AGF-CP will bind this RAN UE NGAP ID with the Session ID as received in Step 4 for transporting the NAS message between the 5G-RG and the AMF. Further NAS messages between the 5G-RG and the AMF will be forward with this binding.

9. After reception of the Registration Request, the 5GC may request for the identity of the 5G-RG in the form of SUCI, as per step 5 of TS 23.316 [23] clause 7.2.1.1.

   The AMF may also authenticate the 5G-RG (by invoking an AUSF) as per step 6 of TS 23.316 [23] clause 7.2.1.1. The AMF transfers the SUCI and the selected PLMN ID to the AUSF, that executes authentication of the 5G-RG.

10. The AMF sends a NAS Security Mode Command to 5G-RG via AGF-CP to activate NAS security. If the authentication was successful in Step 9 above, EAP-Success message is also encapsulated within this message as per step 7 of TS 23.316 [23] clause 7.2.1.1.

11. The 5G-RG completes authentication, creates a NAS security context and responds with an SMC complete message for the AMF, relayed via the AGF-CP.

12. The AMF may request PEI from the 5G-RG as per step 8, and performs step 9, involving the UDM as per step 9 of TS 23.316 [23] clause 7.2.1.1.

    The AMF sends a request for initial context information in N2 message as per step 10 of clause 7.2.1.1 of TS 23.316 [23]. This may include the RG Level Wireline Access Characteristics received from the UDM.

    The AGF-CP is triggered to send an EAP-Success message to 5G-RG indicating the completion of EAP-5G session.

13. After EAP-Success, VSNCP procedures as per RFC 3772 [44] are used to open a VSNP encapsulated W-CP channel between the 5G-RG and the AGF.

    After this procedure, the vendor specific protocol channel is open for exchanging NAS and AS messages between 5G-RG and AGF-CP. Further NAS messages between the 5G-RG and the AMF, via the AGF-CP, must be inserted as a NAS TLV in the VSNP message as specified in section 9.7, where VSNP fragmentation will be used for NAS fragmentation.

    Further AS messages between the 5G-RG and the AGF-CP must be inserted as a AS TLV in the VSNP message as specified.

a. Step12 from Figure 7.2.1.1 of TS 23.316 [23] follow where the 5GC is notified by the AGF-CP about the 5G-RG context creation.

14. The 5GC sends a NAS registration accept message to the AGF-CP as per step 13 of clause 7.2.1.1 of TS 23.316 [23]. This is conveyed to the 5G-RG via the newly established NAS channel in step 13 above.

15. The 5G-RG sends a NAS registration complete message via the AGF-CP to the 5GC, followed by step 15 in section 7.2.1.1 in TS 23.316 [23].

    Note: For internal 5GC exchange of information, TS 23.316 [23] is the reference.

8.2.2 5G-RG Service Request Procedure via W-5GAN

In the general 3GPP case, the Service Request Procedure is initiated when there is no signaling connection between the UE, eNB and 5GC, but the UE is still registered in the 5GC. In W-5GAN access, this means that the AGF does not have any session information available about the 5G-RG stored in it, but the 5G-RG is registered in the 5GC. This implies that there is no initial VSNP connection channel or connectivity established between the 5G-RG and AGF when this procedure is initiated, and the 5G-RG appears as a new device for the AGF.

This procedure is initiated when:

- The AGF resets
- The 5G-RG is still registered in the 5GC, but the VSNP is not open. There is no pre-existing state associated with the RG in the AGF. The service request message from the 5G-RG triggers a VSNP response to open the channel.
- The Link has Flapped but the de-registration timer in the 5G-RG did not expire before connectivity was restored.

  The net result for the individual subscriber is the same as that for an AGF reset. The difference being that the AGF performed a graceful AN release and N2 context release as well as closing the VSNP channel.

  Note: A 5G-RG reset, or a link flap that exceeds the deregistration timer does not trigger the service request procedure as the 5G-RG will go through full registration and PDU session establishment.

This procedure is to be used by the 5G-RG

- In CM-IDLE state to request the re-establishment of the NAS signaling connection and re-establishment of UP for all or some PDU sessions associated to W-5GAN/non-3GPP access.
- In CM-CONNECTED state to request the re-establishment of UP for one or more PDU sessions associated to W-5GAN/non-3GPP access. Note the procedures described do not envision a use case for this scenario.

The procedure described below is initiated by the 5G-RG in CM-IDLE state and is as per clause 7.2.2.2 of TS 23.316 [23] with the following details/clarifications:

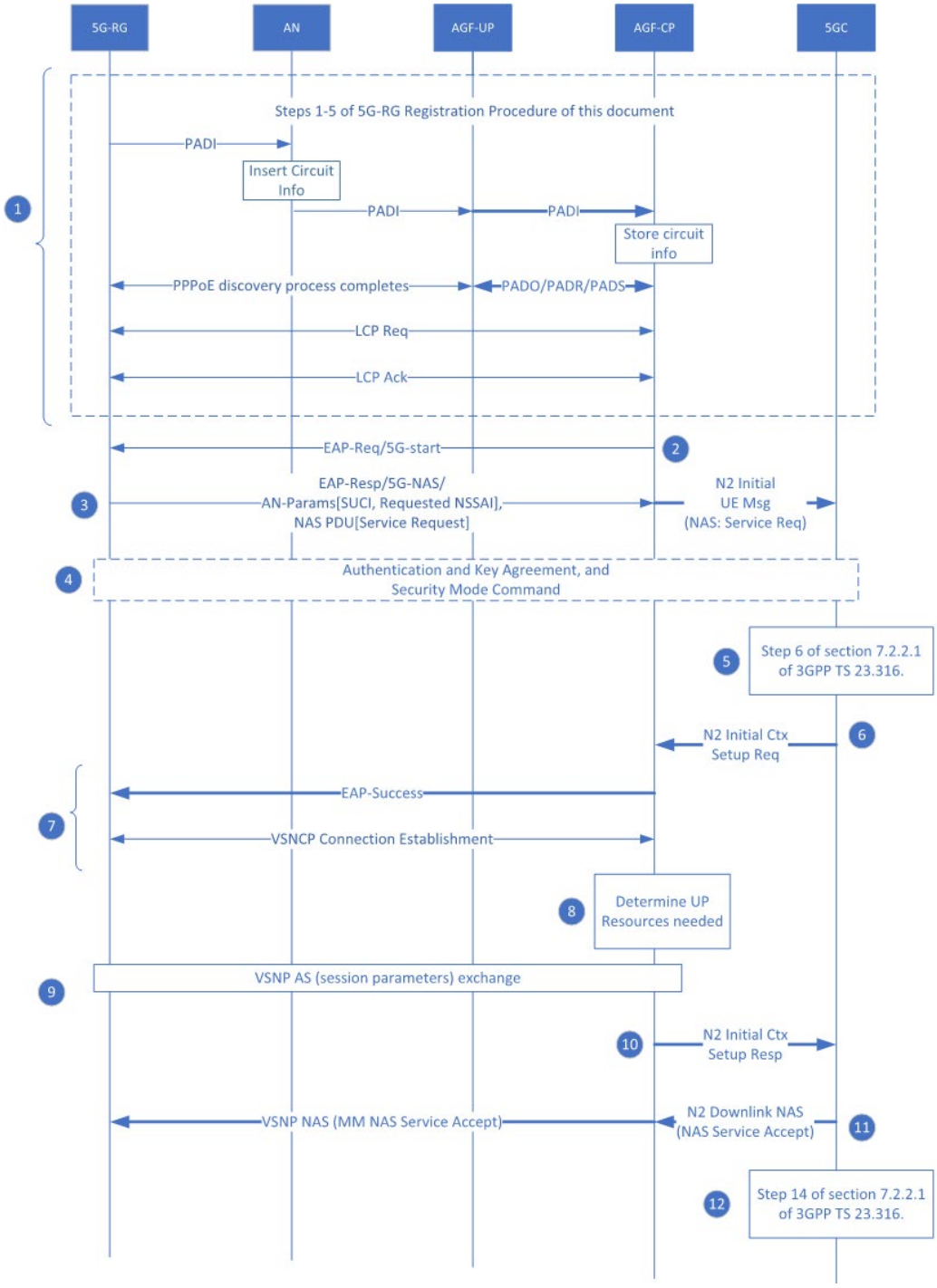


Figure 22: 5G-RG Triggered Service Request Procedure via W-5GAN

1. The 5G-RG connects to AGF-CP as per the 5G-RG registration procedure.

2. The AGF-CP sends an EAP Request/5G-Start to the 5G-RG as per section 8.2.1 (Registration Management Procedure for 5G-RG).

3. The 5G-RG sends the AN parameters and a NAS Service Request towards the 5GC via the AGF-CP in the EAP-Response as per step 3 of clause 7.2.2.1 in TS 23.316 [23]. The AGF-CP forwards this Service Request to the 5GC within an N2 Initial UE message.

4. The 5GC initiates the NAS authentication procedure if the Service Request is not integrity protected as per step 5 of clause 7.2.2.1 in TS 23.316 [23].

5. Step 6 is executed in 5GC as per clause 7.2.2.1 in TS 23.316 [23].

6. The 5GC sends a N2 UE Initial Context Setup Request which contains the N2 SM information received from SMF(s), RG Level Wireless Access Characteristics, and other parameters to the 5G-RG as per step 7 of clause 7.2.2.1 in TS 23.316 [23].

   Note: This single message can setup the UP for several PDU sessions and some aspects of AS design are proposed based on this.

7. The AGF-CP is triggered to send an EAP-Success message to the 5G-RG which leads to the establishment of the VSNP channel where NAS messages can be transported between 5G-RG and AGF-CP as per step 8 and step 9 of clause 7.2.2.1 in TS 23.316 [23].

8. For every established PDU session, the AGF-CP determines which UP resources are required.

9. For every established PDU session, the AGF-CP and AGF-UP set up the UP resources via local configuration and/or AS exchange with the 5G-RG. This corresponds to step 11 of clause 7.2.2.1 in TS 23.316 [23].

10. After setting up the UP resources for all PDU sessions, the AGF-CP sends a N2 Initial Context Setup Response to the 5GC a per step 12 of clause 7.2.2.1 in TS 23.316 [23].

11. The 5GC sends a NAS Service Accept towards the message to the AGF-CP as per step 13 of clause 7.2.2.1 in TS 23.316 [23].

12. Further steps are executed in 5GC as per step 14 of clause 7.2.2.1 in TS 23.316 [23].

For the 5G-RG in CM-CONNECTED state and initiating the service request procedure as per clause 7.2.2.2 of TS 23.316 [23], the below clarifications are provided:

i. The service request from the 5G-RG in step 3 above consists of only the List of PDU Sessions To Be Activated and List of Allowed PDU sessions as per step 1 of clause 4.2.3.2 in TS 23.502 [27].

ii. This is followed by execution of steps 4 and 5 described above.

iii. The 5GC sends only the N2 SM information to the 5G-RG for step 6 described above, as per step 7 of clause 7.2.2.1 in TS 23.316 [23].

iv. Step 7 is executed as specified above where VSNP channel is established between 5G-RG and AGF-CP.

v. Steps 8 and 9 which are associated with UP resource setup also occur in this scenario.

vi. Steps 10-12 are executed for this scenario as specified above.

For 5G-RG in CM-CONNECTED state with network-initiated service request procedure, refer to clause 7.2.2.1 in TS 23.316 [23], which is in turn based on clause 4.2.3.3 of TS 23.502 [27].

8.2.3 5G-RG PDU Session Initiation/Establishment via W-5GAN

Figure 23 shows the call flow and message exchanges for the 5G-RG PDU Session Establishment Procedure via the W-5GAN.

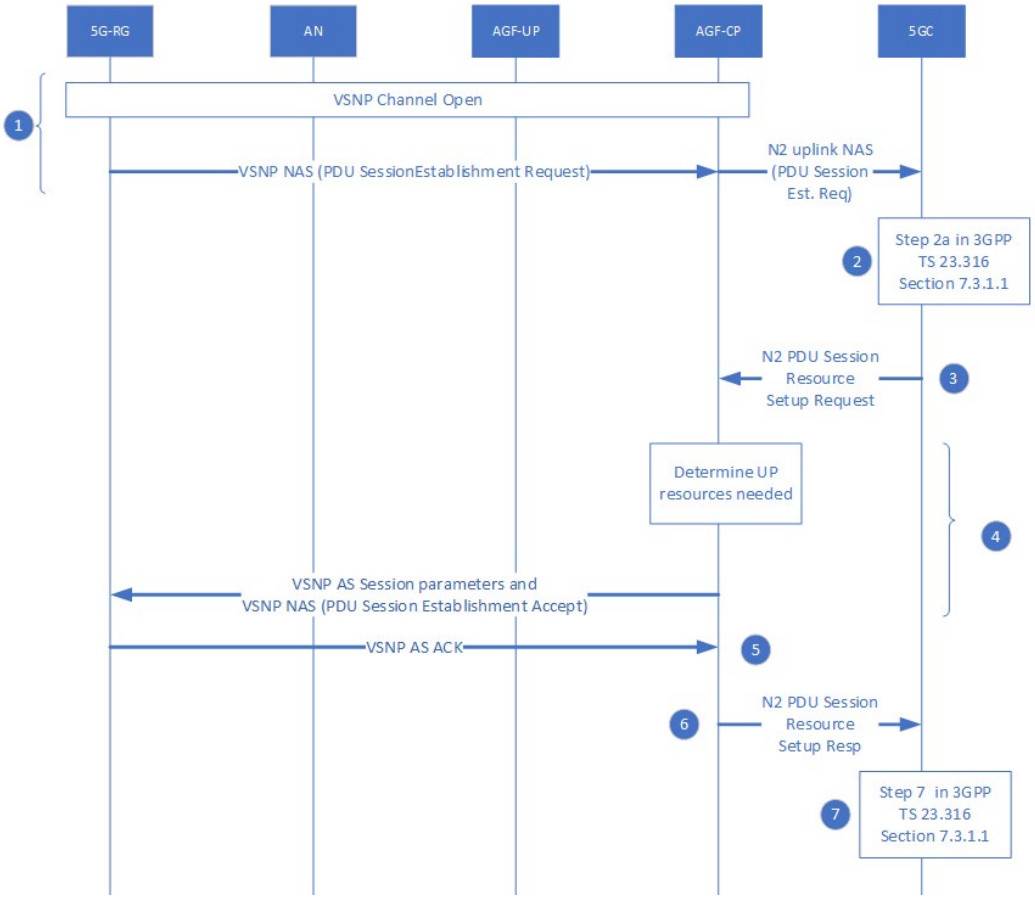


Figure 23: Call flow for 5G-RG Session Establishment via W-5GAN

1. For initiating PDU session establishment, it's a prerequisite that a VSP channel is established and open between the 5G-RG and AGF-CP.

   The 5G-RG creates a PDU Session Establishment Request. This request first reaches the AGF-CP via the VSP NAS channel as per step 1 of clause 7.3.1.1 in TS 23.316 [23].

   The AGF-CP forwards this message to the 5GC in uplink NAS message as per step 1 of clause 7.3.1.1 in TS 23.316 [23]. PCO is a part of this message.

2. On reception of the PDU Session Establishment Request, step 2a of clause 7.3.1.1 is executed in TS 23.316 [23].

3. The 5GC sends a N2 PDU Session Request message to the AGF-CP as in step 2b of clause 7.3.1.1 is executed in TS 23.316 [23]. Included in this message is an encapsulated PDU session accept message to be relayed to the 5G-RG upon completion of AN resource configuration.

4. The AGF-CP determines the UP resources for the PDU session based on the response from the 5GC as per step 3 of clause 7.3.1.1 is executed in TS 23.316 [23].

   The AGF-CP next sets up the UP resources in the AN for the 5G-RG as per step 4a of clause 7.3.1.1 executed in TS 23.316 [23]. Details are communicated to the 5G-RG via VSNP AS exchange.

The AGF-CP can set up the UP resources with the 5G-RG via establishing a 5WE Session. After receiving N2 SM information from the SMF, the AGF-CP will generate AS session parameters and send them to the 5G-RG via VSNP AS message. The AS session parameters contains:

- (a) the identity of the PDU Session associated with this 5WE Session
- (b) QFI(s) associated with the 5WE Session and the default QFI,
- (c) optionally an 802.1Q value and a DSCP value associated with each QFI,
- (d) the PDU Session user plane identification as a 5WE Session ID.

If 802.1Q PCP/DSCP value is included, the 5G-RG and AGF-UP will mark all traffic for this PDU Session and QFI with the indicated 802.1Q PCP/DSCP value. If not present, the AGF and 5G-RG will revert to local configuration of the QFI mapping to 802.1Q PCP/DSCP value.

The AGF-CP sends the PDU Session Establishment Accept NAS IE received from the AMF encoded as a NAS TLV in a common SDU with an AS Session parameters TLV. This is based on Step 5 of clause 7.3.1.1 of TS 23.316 [23].

The AS session parameters and AS Acknowledge Response are carried within the VSNP AS message as specified Section 5, with 5WE Session ID to use indicated in the discriminator portion of the session parameters information.

If the AGP-CP decides there is no suitable UP resources to be setup for the PDU Session, Step 4 and Step 5 will be skipped and AGF-CP will directly sends a PDU Session Request Resource Setup Response to 5GC where the *PDU Session Resource Setup Unsuccessful Transfer* IE must be included containing a cause value as defined in TS38.413 [16].

5. When receiving the AS session parameters and the PDU Session Establishment Accept message, the 5G-RG sends a AS Acknowledge Response with an indication of accept or reject, and optionally a reason of rejecting.
6. The AGF-CP relays a PDU Session Request Resource Setup Response to the 5GC based on step 6 of clause 7.3.1.1 as executed in TS 23.316 [23] after receiving the VSNP AS ACK message for the 5G-RG. The 5G-RG can send first uplink data to the UPF with the received AS parameters to encapsulate the data packet
7. This is followed by execution of step 7 of clause 7.3.1.1 in TS 23.316 [23] in 5GC. If there is no IP address/prefix included in the PDU Session Establishment Accept NAS IE, the 5G-RG will request the IP address/prefix via the established PDU Session using DHCP/DHCPv6 as specified in section 5.8.2 of TS23.501 [26]. The UPF can send first downlink data to the 5G-RG with the allocated IP address/prefix as Destination IP.

8.2.4 ACS Discovery

The 5G-RG can perform ACS Discovery as specified in clause 7.3.1.2 of TS 23.316 [23] and the ACS Discovery mechanism specified in clause 9.6.2 of TS 23.316 [23] is applicable.

As per clause 9.6.2 of TS 23.316 [23], the ACS information may be provided to the RG:

- Via DHCP interaction

  The RG sends a DHCPv4 Request, requesting for ACS information, and receives the same from the DHCP server.

- Via PCO during PDU session establishment procedure as in step 1 of section 8.2.3.

In case the SMF is to provide ACS information to the RG (via PCO or DHCP), it gets the ACS information from SMF subscription data. A DHCP server external to the SMF may also provide ACS information.

8.2.5 Deregistration Procedure for 5G-RG

Figure 24 shows the call flow for the deregistration of a 5G-RG from the 5GC. The deregistration procedure can either be 5G-RG initiated or 5GC-initated.

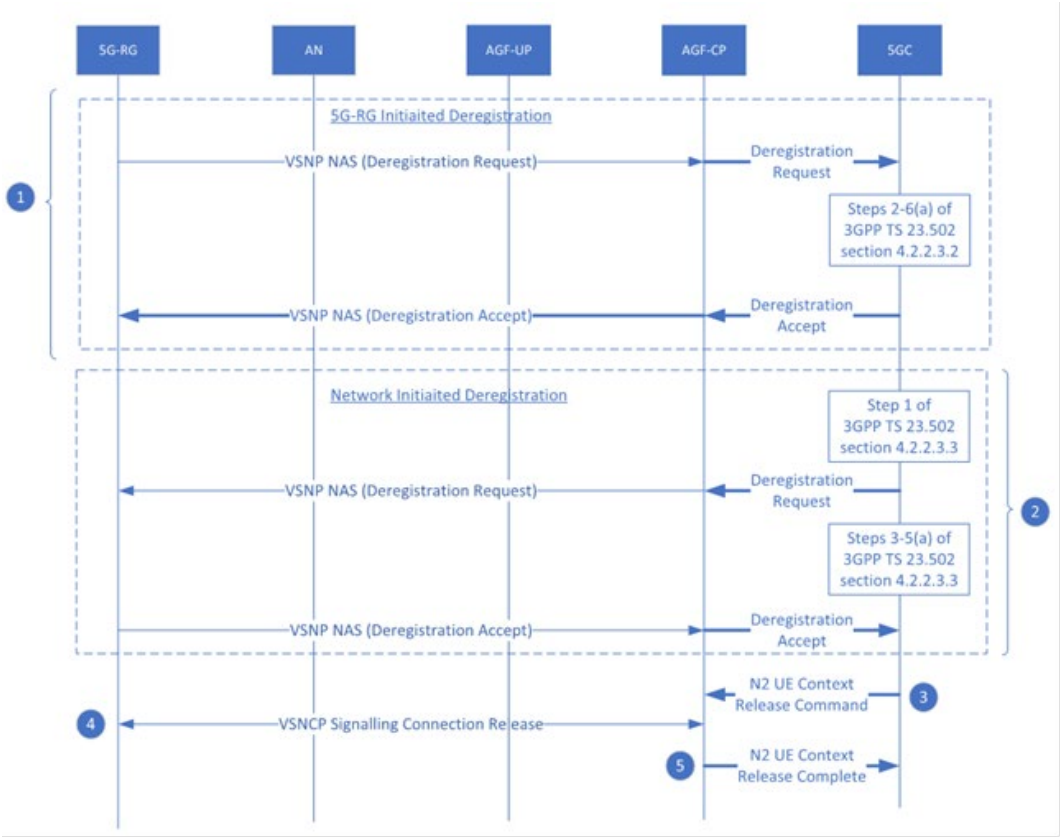


Figure 24: Call flow for the deregistration procedure for a 5G RG

1. The deregistration procedure for the 5G-RG from the 5GC network can be initiated by the 5G-RG itself and is specified in step (1a) of clause 7.2.1.2 in TS 23.316 [23], which is in turn based on UE-initiated deregistration procedure in TS 23.502 [27], clause 4.2.2.3.2.

   The 5G-RG sends a deregistration request towards the 5GC via the AGF-CP. This is followed by session release and policy termination mechanisms in 5GC. The 5GC then sends a deregistration accept message towards the 5G-RG via the AGF-CP.

2. The 5GC can also initiate the deregistration procedure towards the 5G-RG which is specified as Network-Initiated Deregistration in step (1b) of clause 7.2.1.2 in TS 23.316 [23], which is in turn based on clause 4.2.2.3.3 of TS 23.502 [27].

   A deregistration notification is first received from the UDM which triggers the AMF to send a deregistration request to the 5G-RG. This is followed by some message exchanges with the UDM, session release and policy termination.

   The 5G-RG sends a deregistration accept message to the 5GC via the AGF-CP.

3. The 5GC next sends a N2 UE Context Release Command to the AGF-CP as in step 2 of clause 7.2.1.2 in TS 23.316 [23].

4. The AGF-CP releases the signaling connection with the 5G-RG as in step 3 of clause 7.2.1.2 in TS 23.316 [23] and in the LCP procedures section of NAS and AS Transport and Information Elements in this document.

5. After the signaling connection is released with the 5G-RG, the AGF-CP sends a N2 UE Context Release Command message to the 5GC as in step 4 of clause 7.2.1.2 in TS 23.316 [23].

   Note: The cause for the 5G-RG to initiate the deregistration procedure (or why the 5G-RG initiates this procedure) is for FFS and is described here for completeness. It implies a very graceful shutdown of connectivity for a fully functioning system that is normally just left on.

   Note: A network-initiated deregistration is due to the loss of connectivity (and deregistration timer expiry) or business related procedure where the subscriber is deactivated by UDM action (e.g., if the subscriber fails to pay their bills).

8.2.6 5G-RG or Network Requested PDU Session Modification via W-5GAN

The PDU session modification procedure for the 5G-RG, described in Figure 25, is as per clause 7.3 of TS 23.316 [23] with the following clarifications:

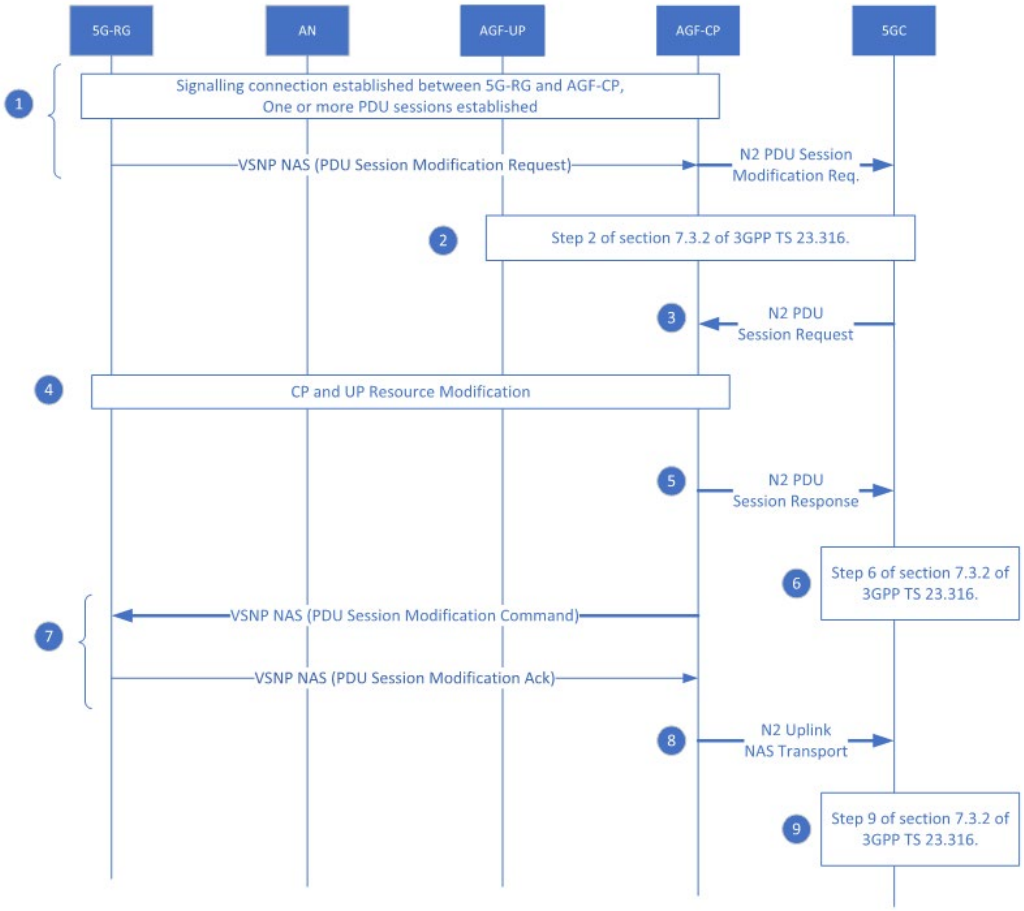


Figure 25: 5G-RG or Network Requested PDU Session Modification via W-5GAN

1. For initiating this procedure, it is a prerequisite that connectivity exists between the 5G-RG and AGF-CP and has at least one PDU session established.

   The 5G-RG creates a PDU Session Modification Request and sends it to 5GC via the AGF-CP as per step 1 of clause 7.3.2 in TS 23.316 [23].

2. This is followed by execution of step 2 of clause 7.3.2 in TS 23.316 [23].

3. The 5GC sends a N2 PDU Session Resource Modify Request to the AGF-CP as per step 3 of clause 7.3.2 in TS 23.316 [23].

4. The AGF-CP initiates the resource modification procedure for the CP and UP resources as per step 4 of clause 7.3.2 in TS 23.316 [23]. If there was any QoS flow added or removed, the AGF sends AS TLV updates to the 5G-RG with an updated set of QFI to PCP/DSCP mapping information.

5. The AGF-CP sends a N2 PDU Session Resource Modify Response towards 5GC as per step 5 of clause 7.3.2 in TS 23.316 [23].

6. The 5GC executes step 6 of clause 7.3.2 in TS 23.316 [23].

7. The AGF-CP sends the PDU Session Modification Command to 5G-RG and receives the PDU Session Modification Ack from the 5G-RG as per step 7 of clause 7.3.2 in TS 23.316 [23].

8. The AGF-CP forwards the PDU Session Modification Ack in an Uplink NAS Transport Message towards the 5GC as per step of clause 7.3.2 in TS 23.316 [23].

9. This is followed by execution of step 9 of clause 7.3.2 in TS 23.316 [23] in 5GC.

8.2.7 5G-RG or Network Requested PDU Session Release via W-5GAN

The PDU session release procedure for the 5G-RG, described in Figure 26, is as per clause 7.3.3 of TS 23.316 [23] with the following clarifications:

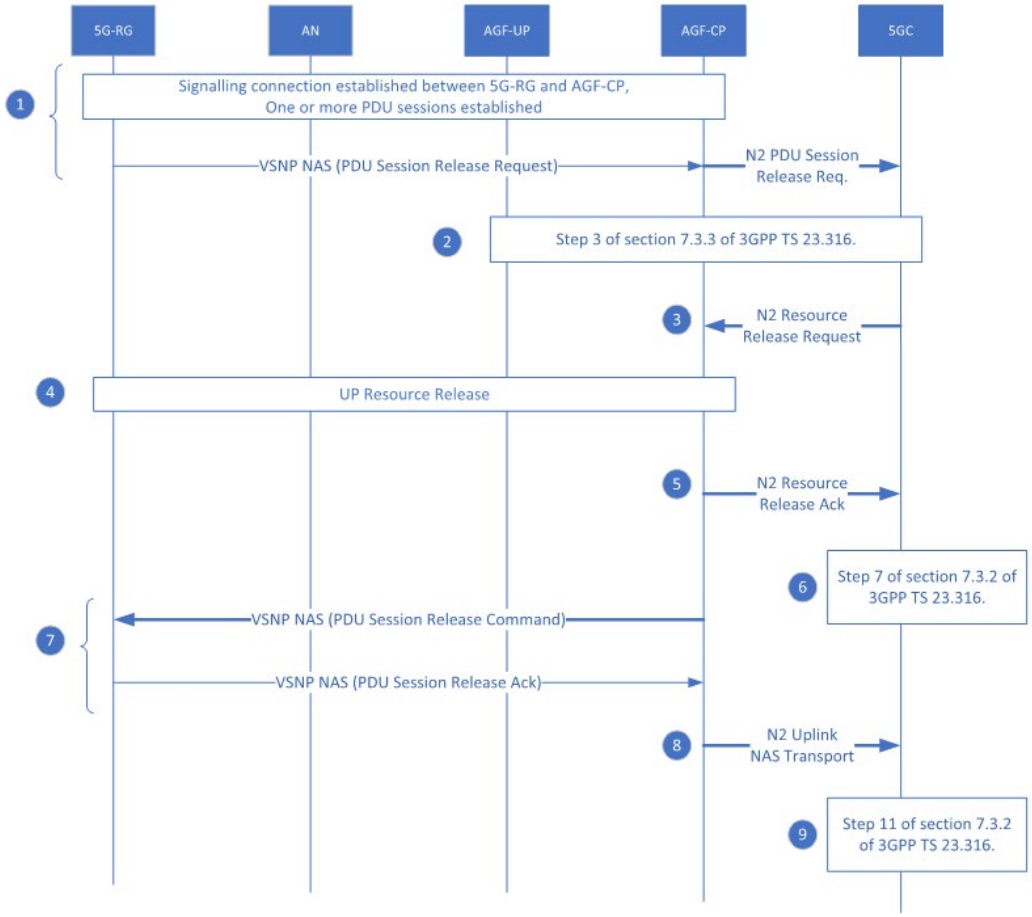


Figure 26: 5G-RG or Network Requested PDU Session Release via W-5GAN

1. For initiating this procedure, it is a prerequisite that connectivity exists between the 5G-RG and AGF-CP and has at least one PDU session established as per step 1 of clause 7.3.3 in TS 23.316 [23].

   The 5G-RG creates a PDU Session Release Request for the 5GC, which is forwarded by the AGF-CP as per step 2 of clause 7.3.3 in TS 23.316 [23].

2. The 5GC executes step 3 as in clause 7.3.3 in TS 23.316 [23].

3. The AGF-CP receives a N2 Resource Release Request from the 5GC as per step 4 of clause 7.3.3 in TS 23.316 [23].

4. Upon receiving the N2 Release Request message, the AGF-CP triggers the release of the corresponding UP resources and CP resources as per step 5 of clause 7.3.3 in TS 23.316 [23].

   This release process is purely a local action where the resources are entirely state and scheduler appearances.

5. The AGF-CP sends a N2 Release Ack towards the 5GC as per step 6 of clause 7.3.3 in TS 23.316 [23].

6. Step 7 is executed in 5GC as per clause 7.3.3 in TS 23.316 [23].

7. The AGF-CP sends a PDU Session Release Command towards the 5G-RG in a NAS message as per step 8 of clause 7.3.3 in TS 23.316 [23].

   The 5G-RG responds towards the AGF-CP with a PDU Session Release Ack in a NAS message as per step 9 of clause 7.3.3 in TS 23.316 [23].

8. The AGF-CP forwards the PDU Session Release Ack in an Uplink NAS Transport Message towards the 5GC as per step 10 of clause 7.3.3 in TS 23.316 [23].

9. Step 11 is executed in 5GC as per clause 7.3.3 in TS 23.316 [23].

8.2.8 5G-RG AN Release via W-5GAN

The AN Release Procedure for the 5G-RG is used to release the NG-AP signaling connection and the associated N3 user plane connections between the W-5GAN and the 5GC. This procedure moves the 5G-RG from CM-CONNECTED to CM-IDLE in 5GC, and the 5G-RG related context information is deleted in the AGF-CP:

It is described in Figure 27 and is as per clause 7.2.5 of TS 23.316 [23] with the following clarifications:

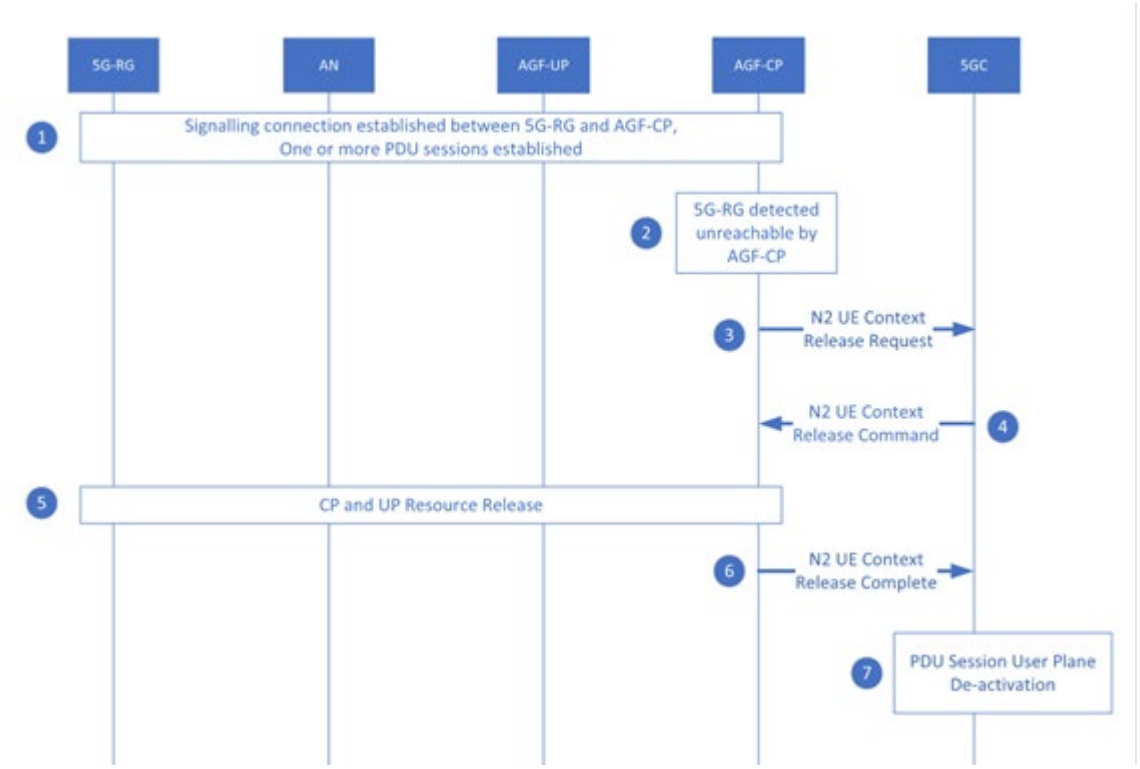


Figure 27: 5G-RG AN Release in AGF

1. It is a prerequisite that the 5G-RG is registered into the 5GC and may have one or more PDU sessions established as per step 1 of clause 7.2.5.2 of TS 23.316 [23].

2. The AGF-CP detects that the 5G-RG is unreachable, which serves as the trigger for initiating this procedure as per step 2 of clause 7.2.5.2 of TS 23.316 [23]. One way to check whether the 5G-RG is reachable or not is via the liveliness check by the LCP protocol using the LCP-ECHO message.

3. The AGF-CP sends a N2 UE Context Release Request to the 5GC as per step 3 in clause 7.2.5.2 of TS 23.316 [23].

4. The AGF-CP receives a N2 UE Context Release Command from the 5GC as per step 4 in clause 7.2.5.2 of TS 23.316 [23].

5. The AGF-CP initiates the release of CP and UP resources between the 5G-RG and AGF-CP as per step 5 of clause 7.2.5.2 of TS 23.316 [23]. The AGF communicates the termination of both PDU sessions and the control connection to the FN-RG via terminating the PPP link via LCP procedures and issuing a PADT message to the 5G-RG as well as releasing and cleaning up all session state for the 5G-RG local to the AGF. This would include 5WE session state, SDF filters and other artifacts of the active PDU sessions.

   Note: The communication of a cause code is FFS.

6. The AGF-CP next sends a N2 UE Context Release Complete to the 5GC as per step 6 of clause 7.2.5.2 in TS 23.316 [23].

7. This is followed by PDU session user plane deactivation in the 5GC as per step 7 of clause 7.2.5.2 in TS 23.316 [23].

8.2.9 CN-initiated selective deactivation of UP connection of an existing PDU session associated with W-5GAN access

The procedure described in TS 23.502 [27] clause 4.3.7 is applicable here for the scenario of W-5GAN access for the 5G-RG and FN-RG in the CM-CONNECTED state with the following clarifications:

1. NG-RAN is replaced by AGF.

2. The release of the user plane resources between the 5G-RG/FN-RG and AGF-CP is based on the procedures local to the AGF and 5G-RG.

8.2.10 5G-RG Configuration Update Procedure via W-5GAN

The 5G-RG Configuration Update procedure is used to update the 5G-RG configuration as per clause 7.2.3.1 in TS 23.316 [23] which includes:

- Access and Mobility Management related parameters like Configured NSSAI and its mapping to Subscribed S-NSSAIs, Allowed NSSAI and its mapping to Subscribed S-NSSAIs.

  When 5GC wants to change the 5G-RG configuration for access and mobility management related parameters, it initiates the procedure described in section 8.2.10.1 (5G-RG Configuration Update procedure for Access and Mobility Management related parameters).

- 5G-RG policy provided by PCF.

  When the PCF wants to update new UE policies in the 5G-RG, it initiates the procedure described in section 8.2.10.2 (5G-RG Configuration Update procedure for transparent Policy delivery).

  Note: This procedure is transparent to the AGF, that is, it does not put any requirements on the AGF. It is included in this document so that the procedure descriptions have a common repository.

8.2.10.1 5G-RG Configuration Update procedure for Access and Mobility Management related parameters

This procedure can be further elaborated below based on clause 7.2.3.1 of TS 23.316 [23], which is in turn based on clause 4.2.4.2 of TS 23.502 [27]:

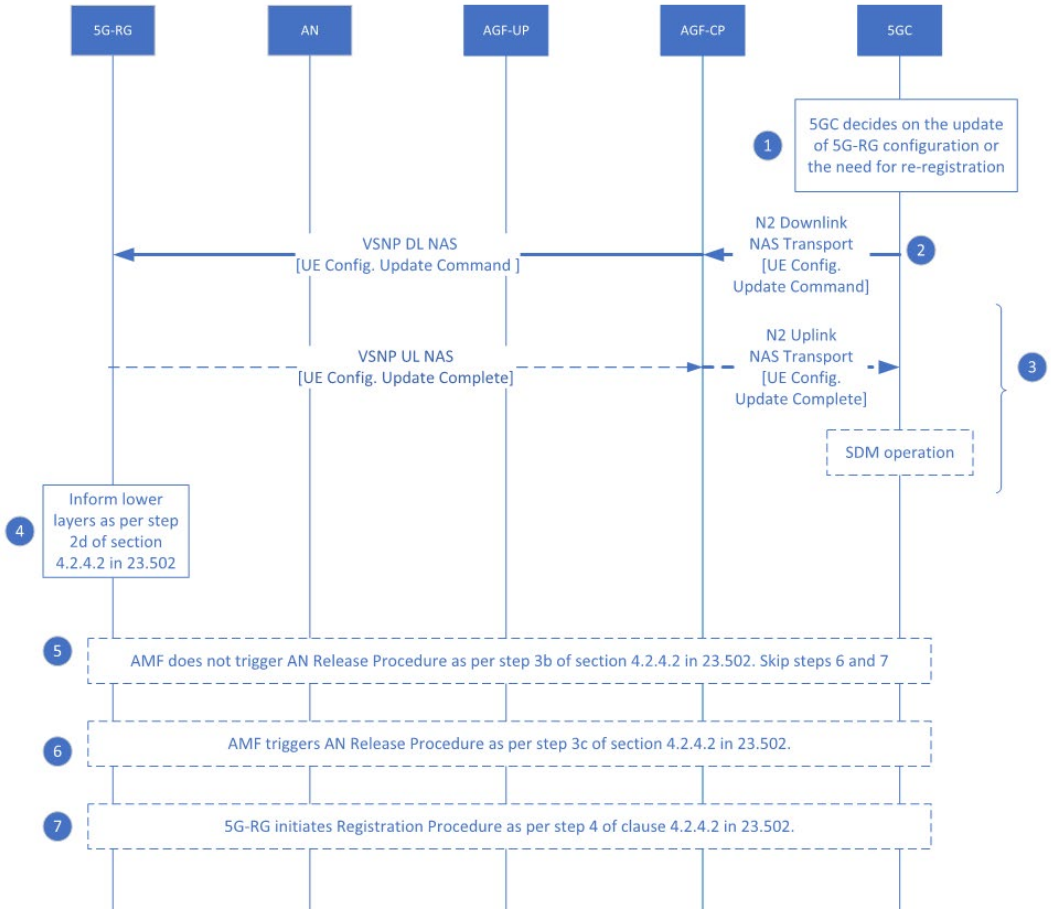


Figure 28: 5G-RG Configuration Update Procedure for access and mobility management related parameters via W-5GAN

1. The 5GC determines the need for 5G-RG configuration update or the re-registration procedure as per step 0 of clause 4.2.4.2 in TS 23.502 [27].

   If the 5G-RG is in CM-IDLE state, the 5GC waits until the 5G-RG is in CM-CONNECTED state as Network Triggered Service Request is not applicable in this scenario.

2. The 5GC sends a NAS Configuration Update Command to the AGF-CP in an N2 Downlink NAS Transport message with one or more 5G-RG configuration parameters as per step 1 of clause 4.2.4.2 in TS 23.502 [27]. The AGF-CP relays this message to the 5G-RG in the VSNP channel established between the 5G-RG and AGF-CP.

   Note: Refer to sub-clause 8.2.19 in TS 24.501 [11] for more details on IEs (Information Elements) for the message “Configuration Update Command” and sub-clause 9.2.5.2 of TS 38.413 [16] for IEs on “Downlink NAS Transport” message.

3. If applicable, the 5G-RG sends an acknowledgement for the UE Configuration Update Indication (if set in the message in step 2 above) via the Configuration Update Complete message as per step 2a

of clause 4.2.4.2 in TS 23.502 [27]. This NAS message is sent to the AGF-CP through the established VSNP channel and then relayed to the 5GC in an N2 Uplink NAS Transport message.

The 5GC may also perform an SDM operation to indicate to the UDM that the 5G-RG has received the subscription change indication as per step 2b of clause 4.2.4.2 in TS 23.502 [27].

Step 2c of clause 4.2.4.2 in TS 23.502 [27] is not applicable here

4. If the 5G-RG is configured with a new 5G-GUTI above and registered to both wireless and 3GPP access, it informs the 3GPP access' lower layers about the new configuration update information as per step 2d of clause 4.2.4.2 in TS 23.502 [27].

5. Step 3a of clause 4.2.4.2 in TS 23.502 [27] is not applicable here.

   If the existing connectivity to the network slices is not affected with the new parameters sent to the 5G-RG, the 5GC does not release the NAS signaling connection for the 5G-RG after receiving the acknowledgement in step 3 above and no immediate registration is required, as per step 3b of clause 4.2.4.2 in TS 23.502 [27]. The steps 6 and 7 described below are skipped.

6. If the existing connectivity to the network slices is affected due to the update with new parameters, the 5GC in its UE Configuration Update Command message includes the new network slice information as per step 3c of clause 4.2.4.2 in TS 23.502 [27].

   If the 5GC cannot provide the new network slice information, it sends an indication to the 5G-RG to initiate the registration procedure. After receiving the acknowledgement in step 3 above, the 5GC releases the NAS signaling connection for the 5G-RG as per step 3c of clause 4.2.4.2 in TS 23.502 [27].

7. Followed by step 6 above, the 5G-RG initiates the registration procedure after it enters the CM-IDLE state as per step 4 of clause 4.2.4.2 in TS 23.502 [27].

8.2.10.2 5G-RG Configuration Update procedure for transparent Policy delivery

This procedure is initiated by the 5GC (i.e., PCF) to change or provide new 5G-RG policies in the 5G-RG. This is as per clause 7.2.3.1 in TS 23.316 [23], which is in turn based on clause 4.2.4.3 in TS 23.502 [27]:

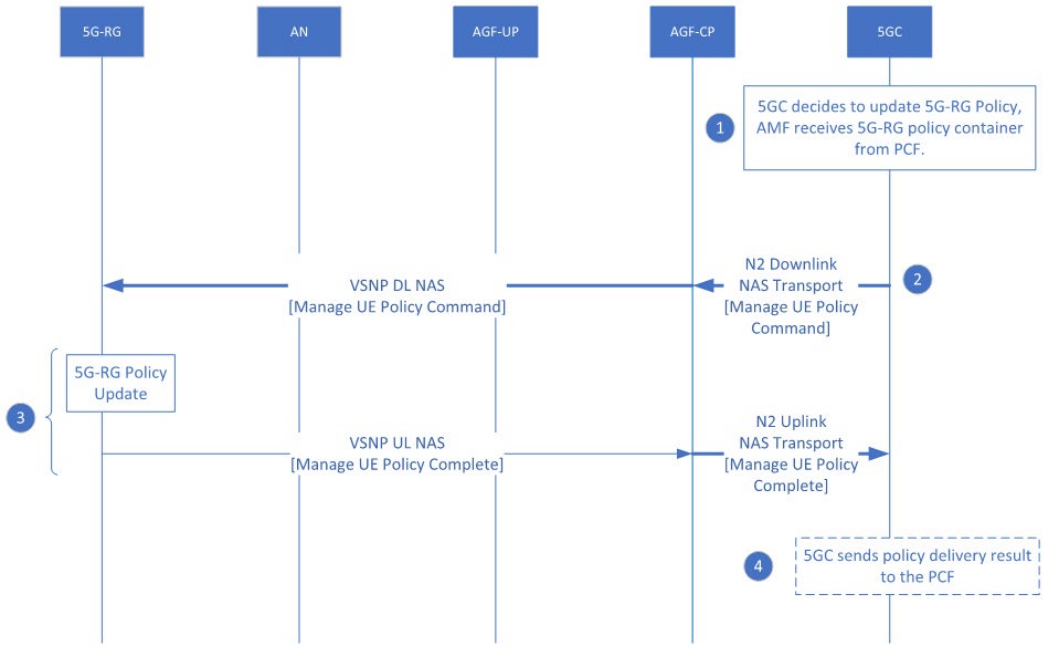


Figure 29: 5G-RG Configuration Update Procedure for transparent UE policy delivery via W-5GAN

1. The 5GC (or PCF) decides to update the 5G-RG policies based on the triggering conditions as per step 0 of clause 4.2.4.3 of TS 23.502 [27].

   The AMF (in 5GC) receives the UE policy container from the policy function (PCF) as per step 1 of clause 4.2.4.3 of TS 23.502 [27].

2. The 5GC sends the policy container in the Manage UE Policy Command message to the AGF-CP in an N2 Downlink NAS Transport message, and the AGF-CP relays this NAS message to the 5G-RG in the established VSNP channel as per step 3 of clause 4.2.4.3 of TS 23.502 [27].

   Note: The IE “Payload Container Type” is set to “UE Policy Container” as per TS 24.501 [11] subclause 8.2.11 and annex D.

3. The 5G-RG updates its policy provided by the 5GC and sends the result to the AGF-CP in a NAS message as Manage UE Policy Complete in the established VSNP channel.

   The AGF-CP relays this message to the 5GC in an N2 Uplink NAS Transport message per step 4 of clause 4.2.4.3 of TS 23.502 [27].

4. The AMF (in 5GC) may send this response from the 5G-RG to the 5GC policy function (PCF) as per step 5 of clause 4.2.4.3 of TS 23.502 [27].

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