

SD-420 5G Fixed Mobile Convergence Study

BBF Wiki

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1 Revision History

Revision Number	Revision Date	Revision Editor	Changes
01	January 12th, 2018	Manuel Paul, PS lead Gregory Dalle, PS lead	Initial document.

Comments or questions about this Broadband Forum Study Document should be directed to help@broadband-forum.org¹.

Editor(s)			
Project Stream Leads	Manuel Paul Gregory Dalle	DTAG Juniper	manuel.paul@telekom.de ² gdalle@juniper.net ³
Work Area Director	Dave Allan	Ericsson	david.i.allan@ericsson.com ⁴

¹ <mailto:help@broadband-forum.org>

² <mailto:manuel.paul@telekom.de>

³ <mailto:gdalle@juniper.net>

⁴ <mailto:david.i.allan@ericsson.com>

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3 Purpose and Scope

3.1 Purpose

The purpose of this study is to find common interfaces for the Access Network and Core Network, to support converged wireline-wireless networks that use the 5G core network.

This project will study N1, N2 and N3 interfaces and provide detailed feedback to 3GPP in the context of 5G Fixed (as recommended by the joint 3GPP-BBF Workshop), to let 3GPP evaluate how to proceed with this as swiftly as possible.

This project will specify a 5G Access Gateway Function (AGF) that adapts fixed access onto the 5G core, and then consider and specify several architectural deployment options as well as the underlying infrastructure sharing aspects.

It will also devise strategies and develop specifications to address a desire by a number of operators for interworking of existing fixed access subscribers and deployed equipment into a 5G core.

With the outcome of this project, BBF will provide recommendations for 5G system architectural and functional integration related to highlighted/identified convergence items during the joint 3GPP-BBF Workshop.

3.2 Scope

This project focuses on the following technical study work,

- Study of the architectural and functional impact on the fixed broadband system of wireline access integration, especially on N1, N2, N3 reference points.
- To identify if there are gaps on User Plane and Control Plane functions, to support fixed access sessions. In particular, this study compares fixed access requirements with functionalities provided by AMF, AUSF, SMF and UPF.
- To address in particular the support by the converged core of the following requirements for fixed access:
 - Session management, including e.g. VLAN tagging modes
 - RG authentication
 - Session authorization and service instantiation
 - End-to-end QoS
- Study and definition of a function, named Access Gateway Function (AGF) in this study document, addressing the support of N2/N3 by a BBF-specified wireline access network, and where in the network such 5G AGF is to be placed. The AGF functionality includes relay of N1, mapping and termination of N2 and N3. It would be the functional equivalent of an eNodeB but where the access media was fixed instead of an air interface. The work will reference the appropriate 3GPP specifications. The AGF functionality may also include mapping and termination N1 in case of support of legacy RG. This study will make recommendations for 3GPP and BBF to further specify such a function (AGF) in standardization.

This project will focus on trusted Non-3GPP access. The timeline of the study will align with the 3GPP roadmap for Rel.15 (study) and Rel.16 (normative).

This project makes recommendations for changes to existing BBF specifications, including nodal behavior modifications and some feature deprecation. The outcome of this project may require modifications to at least the following BBF specifications:

- TR-124 “Functional Requirements for Broadband Residential Gateway Devices”
- TR-69/TR-181 “CPE WAN Management Protocol” and the associated management models
- TR-178 “Multi-Service Broadband Network Architecture and Nodal Requirements”

FMC architectures need to support the case where the Converged Network Operator gets the Wireline Access from an Access wholesaler.

4 References and Terminology

4.1 Conventions

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.

4.2 References

The following references are of relevance to this Study Document. At the time of publication, the editions indicated were valid. All references are subject to revision; users of this Study Document 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.org⁵.

1. [3GPP TS 33.501](#)⁶ - Security Architecture and Procedures for 5G System, Release 15.
2. [3GPP TR 22.261](#)⁷ - Service requirements for next generation new services and markets
3. [3GPP TR 23.799](#)⁸ - Study on Architecture for Next Generation System
4. [3GPP TS 23.501](#)⁹ - System Architecture for the 5G System
5. [3GPP TS 23.502](#)¹⁰ - Procedures for the 5G System
6. [3GPP TS 24.301](#)¹¹ - Non-Access-Stratum (NAS) protocol for Evolved Packet System (EPS): Stage 3
7. [3GPP TS 23.122](#)¹² - Non-Access-Stratum (NAS) functions related to Mobile Station in idle mode

⁵ <http://www.broadband-forum.org/>

⁶ <https://portal.3gpp.org/desktopmodules/Specifications/SpecificationDetails.aspx?specificationId=3169>

⁷ <https://portal.3gpp.org/desktopmodules/Specifications/SpecificationDetails.aspx?specificationId=3107>

⁸ <https://portal.3gpp.org/desktopmodules/Specifications/SpecificationDetails.aspx?specificationId=3008>

⁹ <https://portal.3gpp.org/desktopmodules/Specifications/SpecificationDetails.aspx?specificationId=3144>

¹⁰ <https://portal.3gpp.org/desktopmodules/Specifications/SpecificationDetails.aspx?specificationId=3145>

¹¹ <https://portal.3gpp.org/desktopmodules/Specifications/SpecificationDetails.aspx?specificationId=1072>

¹² <https://portal.3gpp.org/desktopmodules/Specifications/SpecificationDetails.aspx?specificationId=789>

8. 3GPP SA2 Contribution S2-174885, Agreed by SA2#122 meeting in 26 - 30 June, 2017.
9. [TR-069](#)¹³ – CPE WAN Management Protocol
10. [TR-101](#)¹⁴ - Migration to Ethernet-based Broadband Aggregation
11. [TR-124](#)¹⁵ – Functional Requirements for Broadband Residential Gateway Devices
12. [TR-134](#)¹⁶ – Broadband Policy Control
13. [TR-146](#)¹⁷ – IP Session Management
14. [TR-177](#)¹⁸ - IPv6 in the context of TR-101
15. [TR-178](#)¹⁹ - Multi-service Broadband Network
16. [TR-181i2](#)²⁰ - Device Data Model for TR-069
17. [TR-187i2](#)²¹ – IPv6 for PPP Broadband Access
18. [TR-291](#)²² - Nodal Requirements for Interworking between Next Generation Fixed and 3GPP Wireless Access
19. [TR-300](#)²³ - Policy Convergence for Next Generation Fixed and 3GPP Wireless Networks
20. [TR-317](#)²⁴ - Network Enhanced Residential Gateway (NERG)
21. [SD-357](#)²⁵ - Combined 3GPP and BBF Functions
22. [SD-373](#)²⁶ - 5G Requirements and Enablers
23. RFC-3046 DHCP Relay Agent Information Option, Jan 2001.

4.3 Definitions

The following terminology is used throughout this Study Document.

Access Network (AN): A network used by a subscriber device to access a service edge, typically IP edge, i.e. BRAS, BNG, P-GW, 5G core.

Access Type: this parameter represents the type of Access Network used by a subscriber device to access the 5G Core. In the scope of this document the Access Type can represent the Wireline 5G Access Network (W-5GAN), NG-RAN and Non-3GPP. The term Non-3GPP in this study is considered to be a system not defined by 3GPP and that it is not in the scope of BBF.

Wireline Access Network: Access network conforming with TR-101/TR-178, that can be for example optical fiber, electrical cable, or fixed wireless connection. The egress interface of a wireline access network is either V or (N2', N3').

Wireless Access Network: Access Network whose physical media or channel is air, e.g. Cellular, Wi-Fi radio techniques, e.g. egress interface of a 4G cellular access network is S1.

- Cellular Wireless AN
- Wi-Fi Wireline AN

13 <https://www.broadband-forum.org/technical/download/TR-069.pdf>

14 <https://www.broadband-forum.org/technical/download/TR-101.pdf>

15 <https://www.broadband-forum.org/technical/download/TR-124.pdf>

16 <https://www.broadband-forum.org/technical/download/TR-134.pdf>

17 <https://www.broadband-forum.org/technical/download/TR-146.pdf>

18 <https://www.broadband-forum.org/technical/download/TR-177.pdf>

19 <https://www.broadband-forum.org/technical/download/TR-178.pdf>

20 https://www.broadband-forum.org/technical/download/TR-181_Issue-2.pdf

21 https://www.broadband-forum.org/technical/download/TR-187_Issue-2.pdf

22 <https://www.broadband-forum.org/technical/download/TR-291.pdf>

23 <https://www.broadband-forum.org/technical/download/TR-300.pdf>

24 <https://www.broadband-forum.org/technical/download/TR-317.pdf>

25 <https://aro.broadband-forum.org/bin/c5i?mid=4&rid=5&gid=0&k1=44242&tid=1493228384>

26 <https://aro.broadband-forum.org/bin/c5i?mid=4&rid=5&gid=0&k1=46567&tid=1493228432>

Distinguish RG as UE and RG as relay UE for Wi-Fi

Hybrid Access: Access that utilize both wireline access network and wireless access networks. From the perspective of RG, 5G-RG or UE, this can either be exclusive or simultaneous access.

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. They are N'2 for the control plane and N'3 for the user plane.

5G Access Network (5GAN): This comprises 5G radio ANs (NG RANs) and 5G wireline ANs connecting to a 5G core.

Access Gateway function (AGF): A function which added to a wireline AN, allows connectivity to the 5G core.

AGF-CP: The control plane of the AGF is in charge of the mediation between the AN control plane and N2'.

AGF-UP: The user plane of the AGF is in charge of the mediation between the AN user plane and N3'.

5G-RG: An RG acting as UE with regard to the 5G core. It holds a secure element and exchanges NAS signaling with the 5G core.

FN-RG: An RG not supporting direct connection with 5GC Network Function e.g. it does not support 5G NAS. The FN-RG is a RG specified by TR-124i5.

5G Fixed Mobile Interworking Function (FMIF): A function which is added to a wireline AN, allows interworking with the 5G core supporting the interconnection of user plane with UPF and control plane with 5GC Network Functions. The 5G FMIF may also be split into FMIF Control Plane and FMIF User plane to support N1''/N2'' and N3'' in control plane and user plane, respectively.

N1: "Reference point between UE and the AMF" [3GPP TS23.501]

N1': Reference point between 5G-RG and the AMF.

N2: "Reference point between (R)AN and the AMF" [3GPP TS23.501]

N2': Reference point between W-5GAN and the AMF. On the W-5GAN side, the termination point is the AGF-CP.

N3: "Reference point between (R)AN and the UPF" [3GPP TS23.501]

N3': Reference point between W-5GAN and the UPF. On the W-5GAN side, the termination point is the AGF-UP.

4.4 Abbreviations

This Study Document uses the following abbreviations:

AAA – Authentication, Authorization and Accounting

ACS – Auto-Configuration Server (TR-069)

AF – Application Function

AGF – 5G Access Gateway Function

AMF – Access and Mobility Management Function

API – Application Programming Interface

AUSF – Authentication Server Function

BBF – Broadband Forum

BPCF – Broadband Policy Control Function

BNG – Broadband Network Gateway

BRG – Bridged RG
BSS – Business Support Systems
CPE – Customer Premises Equipment
DC – Data Center
DHCP – Dynamic Host Configuration Protocol
DM – Data Model
DN – Data network
FAP – Femtocell Access Point
FTTdp – Fiber To The Distribution Point
FMIF – 5G Fixed Mobile Interworking Function
FWA - Fixed Wireless Access
GW – Gateway
LSL – Logical Subscriber Link
MSBN – Multi-Service Broadband Network
MS-BNG – Multi-Service BNG
NAT – Network Address Translation
NERG – Network Enhanced Residential Gateway
NFV – Network Function Virtualization
NFVI – NFV Infrastructure
OAM – Operations, Administration and Management
OSS – Operations Support Systems
PCF – Policy Control function
PCRF – Policy and Charging Rules Function
PON – Passive Optical Networking
(R)AN – (Radio) Access Network
RG – Residential Gateway
SDN – Software-Defined Networking
SMB – Small/Medium Business
SMF – Session Management Function
STB – Set Top Box
UDM – Unified Data Management
UE – User Equipment
UML – Unified Modeling Language
UPF – User plane Function
USP – User Services Platform

VBG – Virtual Business Gateway

vBNG – Virtual BNG

vG – Virtual Gateway

5GC - 5G Core Network

5 Architecture and Guiding Principles

Today wireline access is served by a wireline core network, comprised of MS-BNGs and servers - typically AAA and policy servers (BPCF) - delivering functions such as user authentication, authorization, accounting, IP addressing, bandwidth management, service policies, and lawful intercept. Attached to the wireline access is CPE that typically interconnects a heterogeneous set of devices deployed at the premises. The emergence of 5G has been identified as an opportunity to converge the wireline and mobile core networks.

SD-420 identifies a set of issues and possible resolution for two new models for fixed networks that take advantage of a 5G converged core network. The two new models that are the focus of this study are:

- The Integration model – in this model, the converged 5G core network is used to deliver functions traditionally offered by the wireline core network. This model assumes a new RG that originates NAS (5G RG) and a new function to mediate between the wireline access network and the converged core network, called the 5G Access Gateway Function (5G AGF).
- The Interworking model – in this model, existing fixed CPE is served by the 5GC. An interworking function (5G Fixed Mobile Interworking Function – 5G FMIF) enables some form of service convergence by linking the wireline core network to the converged core network and proxying NAS on behalf of the legacy RG.

For both these new models there are two different scenarios. In the first, the RG is only connected via the wireline access network, and in the second, the RG is connected to both the wireline access and NG-RAN (so called Hybrid Access mode); note that both access types may or may not be used simultaneously.

Specification of the 5G-RG, AGF and the 5G FMIF will be a BBF responsibility.

Finally, the case of Fixed Wireless Access is considered as part of the integration model, i.e. the 5G-RG is only connected to the NG-RAN and has no wireline connection. The intention being to offer the same service suite as for wireline access.

The intention is for the BBF to specify the wireline aspects of these models such that they can be deployed in existing BBF specified access networks alongside existing fixed access services.

The ability to support coexistence of new service offerings in parallel with existing services in such a fashion is desirable for a number of reasons:

- New service offerings can be incrementally deployed and without disturbing existing customers.
- Coexistence would allow regulatory requirements for L2 unbundling of the access to continue to be supported. L2 wholesale interfaces would continue be supported and provides for a clear separation of interests.
- A clear migration path towards convergence can be defined without a complete forklift of the network
- The addressable market for 5G converged services is maximized.

That these models (and existing legacy service delivery models) are not mutually exclusive. For example, a network service provider may continue to support certain subscribers or services while migrating at least some of their subscribers to using the 5G core via either the integrated or the interworking models.

BBF experts have reviewed TS23.501 and TS23.502 and have identified a number of issues with the support of fixed access networks by the 5GC that potentially will require additional specification work by 3GPP.

Editor's note: Hybrid access, support for UEs subtending a 5G-RG, and the Interworking model, are for FFS w.r.t this version of the document.

6 Key Issue List

6.1 Key Issue 1: Registration and Connection Management Procedures

The scope of this key issue is to study the applicability of the registration management and connection management states and procedures defined by TS 23.501 and TS 23.502, to both the Integration scenario, where the 5G-RG is connected via wireline access (i.e. W-5GAN) and the FWA scenario, where the 5G-RG is connected via NG RAN to the converged core network.

In particular, the key issue will study for the above scenarios:

- applicability of the Registration Management states defined in TS 23.501 clause 5.3.2
- applicability of the Connection Management states defined in TS 23.501 clause 5.5.2
- whether the registration procedures defined in TS 23.502 clause 4.2.2.2 apply and improvements are required to fulfill the above scenarios
- whether the connection procedures defined in TS 23.502 clauses 4.2.3, 4.2.4, 4.2.5, 4.2.6, 4.2.7 and 4.2.8 apply and improvements are required to fulfill the above scenarios
- How to identify the device as a 5G-RG during registration, in particular in the FWA case, where the access type cannot be used, since is not wireline?

The key issue will also consider the applicability of specification related to the support of N3GPP in clause 4.12 of TS 23.501.

This key issue will also study the authentication phase for the 5G-RG in terms of which credentials are supported and how the corresponding authentication is performed.

Key Issue #1 Status - BBF believes it has sufficient information to complete this study item and make any recommendations.

6.2 Key Issue 2: Transport and Encapsulation in the Wireline Access of Control Plane (eg. NAS) and User Plane Traffic Exchanged with 5G Core

There are a number of issues with respect to how 5G NAS and the user plane are transported between the fixed UE (5G-RG) and the AGF. The elements for which solutions are required are:

1. N1 exchange, including
 - Authentication
 - Multiplexing of NAS with L2 configuration information elements, authentication
 - Liveliness
 - Reliable
 - Other 3GPP information (beyond NAS), such as 5G GUTI (Globally Unique Temporary ID) and slicing related information
2. Sharing of the access network between 5G FMC traffic and traffic from legacy services (coexistence of 5G and legacy traffic)
3. How QFI is communicated between the AGF and the 5G-RG and when it is relevant
4. PDU session delineation/disambiguation/encapsulation in the access
5. PDU Session liveliness

6. QoS aspects

Key Issue #2 Status - BBF believes it can make some recommendations. However, we expect that the study of the case where the UE is connected behind the RG as well as hybrid access could impact this key issue.

6.3 Key Issue 3: Regulatory Requirements

With respect to regulatory requirements, what requirements will this place on BBF specified components, and are any changes required to 3GPP procedures. This is in the context of:

1. Location reporting for fixed access
2. Location reporting for FWA
3. Lawful intercept
4. Emergency Services

Key Issue #3 Status - BBF will continue to work on identifying the subset of requirements for 5G FMC. We suggest that 3GPP investigate this issue and provide their view to BBF.

6.4 Key Issue 4: Operational Requirements

5G-RG Management

Beside functions related to control plane and user plane for WAN connectivity, the RG also serves devices in the home LAN, as described in “Key Issue 8: Home LAN Support”. Some of the configuration parameters for LAN functions may come from DHCP on the WAN interface (eg. DNS information, see TR-124 WAN.DHCPC) or from management interfaces (TR-069).

As 5G-RG continues to support the home LAN, it must be manageable by an ACS based on TR-069.

1. How is the IP connectivity set up between the 5G-RG and the ACS? (today this may be done in-band or in a separate IP session, for example with a private IPv4 address)
2. Does TR-069 and/or TR-181 (Device Data Model for TR-069) need to be modified to support 5G FMC?
3. Does 5G-RG need to integrate also with other management systems, specified by 3GPP?

Notes:

- Some managed home devices, such as set-top boxes or voice gateways may also be managed based on TR-069
- BBF is introducing the User Services Platform (USP) as a natural evolution of TR-069, to manage, monitor, upgrade and control connected devices. It includes the management of network interfaces and service functions (IoT functions, VoIP, etc). The impact of USP is FFS and likely relevant for BBF but not for 3GPP.

Key Issue #4 Status - BBF believes it has sufficient information to complete this study item and make any recommendations.

6.5 Key Issue 5: Resource Management in the Access

The wireline access network has finite resources such that requests for network resource may not be able to be honored. This is exacerbated by the requirement for coexistence and the associated sharing of network resources between multiple entities. There are several aspects to this:

1. Ability to reserve resources in the access network
2. Integration of access network resource lifecycle management (reserve, release, modify) into 3GPP procedures.
3. Coordination of configuration of connectivity between the 5G-RG and the AGF.

Note: resource management includes QoS support.

Key Issue #5 Status - BBF believes it has sufficient information to complete this study item and make any recommendations.

6.6 Key Issue 6: Session Management

In TS 23.501, several clauses describe the session management procedures required for non-roaming and roaming scenarios that need to be considered for both the FMC integration and FWA models.

In TS 23.501, the definitions related to "PDU session" are:

- **PDU connectivity service:** a service that provides exchange of PDUs between a UE and a Data Network (DN),
- **PDU session:** association between the UE and a Data Network that provides a PDU connectivity service,
- **PDU session type:** the type of PDU session, which can be IPv4, IPv6, Ethernet or Unstructured.

The IP PDU session is not different from an IP session in BBF terminology. The Ethernet PDU session is applied at Ethernet level. The unstructured PDU session can be a non-IP or a non-Ethernet based session that can represent a proprietary protocol or other type of protocol applied between the UE and DN on the user plane.

The PDU layer corresponds to the PDU carried between the UE and the DN over the PDU session. When the PDU Session Type is IPv6 the PDUs are IPv6 packets, while when the PDU session type is Ethernet the PDUs are Ethernet frames. The Data Network represents the network where the PDU are received and transmitted. The protocol over N3 is currently GTP-U as defined in 3GPP.

Figure 6-1 shows the User plane protocol stack for the FWA model (5G-AN):

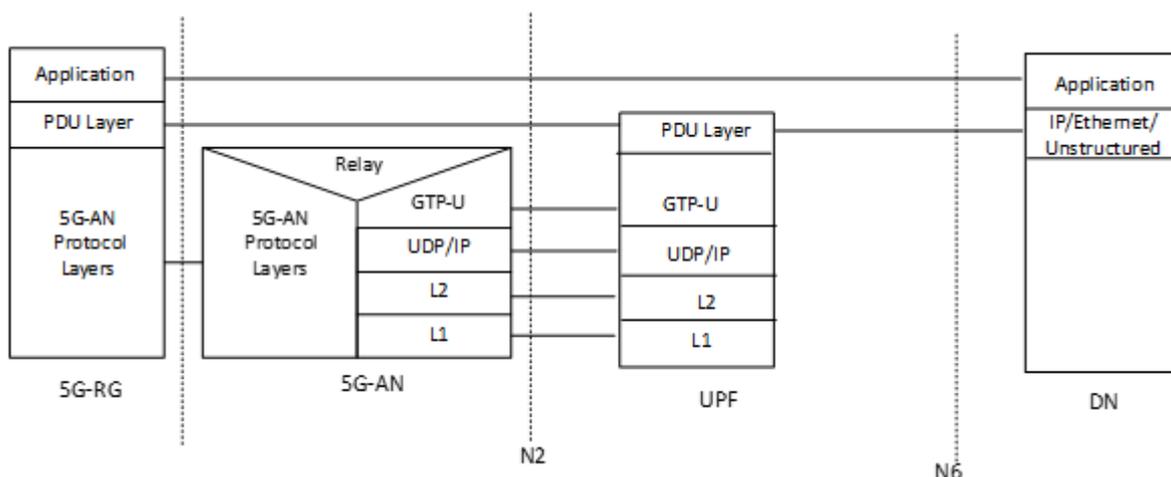


Figure 6-1: FWA Model - User Plane Protocol Stack, modified from TS 23.501

Figure 6-2 shows the User plane protocol stack for the Integration model (W-5GAN). The wireline access node and AGF are not represented individually, as the focus of this clause is the description of PDU session and PDU layer. In addition, the W-5GAN protocol layer represents the presence of wireline specific protocols between 5G-RG and W-5GAN.

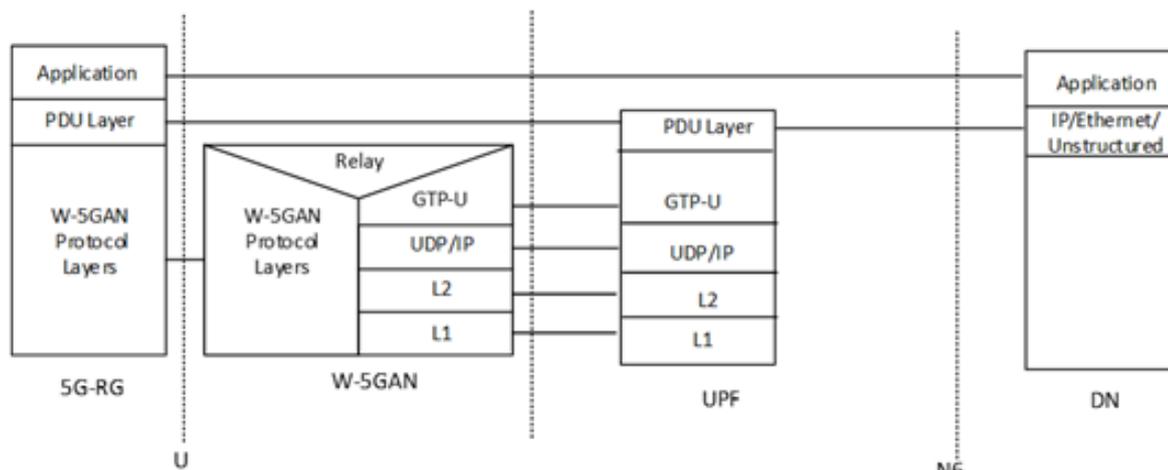


Figure 6-2: Integration Model - User Plane Protocol Stack

Existing Broadband deployment models include the following:

1. Single VLAN per home. Bridged, Routed or Bridged/Routed (combination) RG.
2. Multiple VLANs per home (e.g. different VLAN per service per home). Bridged, Routed or Bridged/Routed (combination) RG.
3. Shared VLANs across homes (N:1). Bridged, Routed or Bridged/Routed (combination) RG.

Bridged and Bridged/Routed RG have the following properties:

- A) They require the service edge (3GPP context 5GC) to identify each device and perform subscriber management at two levels, per-home level and per-device level
- B) The subscriber management level:
 1. Applies access management and bandwidth management to individual device/service
 2. Enforces aggregate bandwidth for the home (i.e. perform HQOS).
- C) Each device within a home requests for IPv4/v6 address directly with the service edge
- D) The RG tags VLAN(s) onto subscriber traffic which can be used to identify the home or different services

Editor's note: the W-5GAN User Plane Protocol stack requires further investigations.

This key issue aims to study:

1. How the PDU sessions are supported in Integration and FWA models and whether current PDU session types fit the needs of FWA and of the Integration scenario.
2. Whether specific improvements and modifications are required to session management procedures defined in 3GPP TS 23.502 clause 4.3 and the specific functionality of W-5GAN in case of Integration FWA models.
3. What the protocol stack is for both control plane (see key issue #2) and user plane of W-5GAN.
4. How the use of Ethernet in 5GCN can be optimized:
 - Study whether and how VLAN models defined in TR-101 (S-VLAN, C-VLAN) can be applied
 - How do we support Network Enhanced Residential Gateway (NERG), defined in BBF TR-317, with Ethernet PDU type
 - Study how VLAN models (S-VLAN/C-VLAN) can be either mapped to GTP or to go towards/directly to UPF
5. For the Bridge RG, study the following issues for both FWA and the Integration model:

- Can PDU session type Ethernet support address assignment where the 5GC handles Ethernet frames also act as a IP gateway (first hop router)?
- Can the 5GC identify individual devices (MAC and IP) with PDU session type Ethernet? The identification will be used for policy enforcement, QoS, and etc.

6. Study the impact of the PDU session on the involved network functions.

The PDU sessions are established upon 5G-RG request, modified upon 5G-RG and 5GC request, and released upon 5G-RG and 5GC request using NAS SM signalling exchanged over N1, between the 5G-RG and the SMF.

Editor's note: the support of Unstructured PDU session requires further investigations

Key Issue #6 Status - BBF is still investigating the support of Ethernet. Hybrid access/ ATSSS and UE connected behind RG may also impact this issue. We anticipate that this will require joint discussions between 3GPP and BBF.

6.7 Key Issue 7: Addressing for IPv4 and IPv6

Currently, 3GPP document (TS 23.501 issue 1.5.0) provides the following ways to assign an IP address to an UE:

- When the PDU session is type IP for IPv4 or PDU type IPv4 (section 5.8.2.2.1)
 - Via SM NAS signaling
 - Via DHCPv4, once PDU session establishes (DHCP server can be the SMF or external)
 - Default-gw, subnet-mask, and DNS can be assigned from PCO (Protocol Configuration Option) or DHCPv4
- When the PDU session is type IP for IPv6 or PDU type IPv6 (section 5.8.2.2.1)
 - Via SLAAC prefix RA according to RFC 4861
 - DHCPv6 stateless for information such as DNS, according to RFC 3736
- When the PDU session is type Ethernet (section 5.6.10.2 Note 2)
 - IP address allocated by the data network as an application layer

The above address assignment might be adequate for an UE but not for traditional RG. There are key differences between an UE and a RG:

1. RG typically have both a WAN side, for uplink and management, and LAN side, for home devices

a. The WAN side is typically dual stacked with an IPv4 address and an IPv6 address or prefix

i. RA (IPv6 Router Advertisement) can also be used to force RG to go through DHCPv6 process instead, specifically using the (M) flag, per RFC 5175

b. The LAN side is also dual stacked

i. The IPv4 addresses assigned are typically private IPv4 addresses which are then translated to the WAN IPv4 IP address, based on NA(P)T

ii. The IPv6 prefix used for the LAN side assignment is assigned through DHCPv6 PD (Prefix Delegation). The prefix length recommended from BBF is /56.

2. The DNS for IPv6 is not limited to RFC 3736 but as well for:

a. RFC 3646, natively on stateful DHCPv6 (example: with DHCPv6 NA and PD)

b. RFC 8106, natively on SLAAC

The gaps between 3GPP and BBF address and DNS assignment is summarized below for PDU session type IP:

	3GPP supported	BBF 5G-RG requirement	Comments
IPv4 addressing	NAS DHCPv4	NAS DHCPv4	
IPv6 addressing	SLAAC	SLAAC DHCPv6 both NA and PD SLAAC (M) flag support	While a /64 SLAAC prefix is adequate for UE application (such as tethering), some operators might not want a /64 SLAAC prefix just for RG management, while preferring DHCP NA for a /128 address.
DNS v4	Protocol Configuration Option PCO* DHCPv4	PCO* DHCPv4	
DNS v6	Stateless DHCPv6	RA option Stateful DHCPv6 Stateless DHCPv6	Instead of multiple DHCP requests, the DNS can be a native option in RA or stateful DHCPv6
Default gateway IPv4	PCO* DHCPv4	PCO* DHCPv4	
Default gateway IPv6	Router Advertisement	Router Advertisement	Requires UPF/SMF to support IPv6 Router Advertisement
Subnet Mask IPv4	N/A to PCO* Provided by DHCPv4	N/A to PCO* Provided by DHCPv4	
Options	PCO*	DHCPv4 SLAAC DHCPv6	SMF and UPF should be agnostic to address options, as they act as a proxy/relay

Note: cells colored in red in this table indicate a potential gap between BBF requirements and what is currently in 3GPP release 15.

It is assumed that for LTE core, PCO can provide a method to indicate DNS, subnet mask, and default gateway parameters. For 5GC, is PCO the correct method to retrieve DNS, subnet mask and default gateway? If not, 3GPP should inform BBF of the proper method.

If PDU type Ethernet was to support an IP gateway (see issue 6), then the SMF/UPF will be responsible for responding to DHCPv4 and DHCPv6 request message (including DNS, default gateway and subnet mask). The IP gateway will also be responsible for SLAAC address assignment (including DNS).

Key Issue #7 Status - Beside the question to 3GPP with regards to PCO, BBF believes it has sufficient information to complete this study item and make any recommendations.

6.8 Key Issue 8: Home LAN Support

For fixed broadband services, the Residential gateway acts as a UE. The RG has one or multiple WAN connections toward the access network(s) and one or multiple wired or wireless (Wifi) connections toward the home LAN. End user devices (desktop, laptop, smartphones and tablets, printers, smart TV, servers, IoT devices, etc) are part of the home LAN. The home LAN may also host managed service provider devices such as set top boxes and voice gateways (either standalone or integrated in the RG). In general, the RG acts as a router and NAT between the LAN (private IPv4 subnet) and the WAN (public IPv4 address). The RG also supports IPv6.

TR-124 defines functional requirements for the RG, in particular the following sections related to Home LAN support: LAN.GEN, LAN.ADDRESS, LAN.ADDRESSv6, LAN.DHCPS, LAN.DHCPv6S, LAN.DNS, LAN.DNS6, LAN.NAT, LAN.PFWD, LAN.PFWDv6, LAN.FWD, LAN.QOS, LAN.FW, LAN.SIP, LAN.IGMP.

Can we continue to provide public IPv4 addresses on the RG WAN interface? In particular, how do we avoid double NAT (in RG and Carrier Grade NAT) for fixed services? More broadly, the Core Network must permit different services (equivalent to today's Gi LAN services) for fixed and mobile services.

How do we support fixed public IPv4 address on the RG and enable a server (eg. web server, FTP server,...) hosted on the home LAN to be reachable from the Internet based on this IPv4 address?

What are the supported use cases to apply differentiated behaviors per home device, for example: per device charging, Lawful Intercept, QoS, filtering, value added services (eg security, parental control), troubleshooting (for examples of use cases, see TR-317 NERG).

How to have per home devices authentication and authorization?

i. In the case the home device is a UE: can 802.1x / EAP-AKA or EAP-AKA' continue to apply, as defined in TR-124 LAN.Interworking.UE-Authentication?

ii. In the case the home device is not a UE: can Network Enhanced Residential Gateway (NERG / TR-317) be supported by the 5G Core Network, which assumes a L2 session between the home LAN and the network based virtual Gateway

Is RG as a relay UE a valid use case, how does it apply to devices in the home?

What are the identifiers used by the Core Network functions to identify a home device?

Can different devices that are in the same home LAN be part of different network slices?

Do we need to extend QoS signaling beyond the RG, into the home LAN?

How do we support nomadicty, where a UE must receive the same services and policies when attached via a RG (at home / wifi) and when attached to the radio access network?

Editor's note: home LAN extension with devices that are outside of the home area network (see BBF TR-317 and 3GPP 5G LAN study) is FFS.

Key Issue #8 Status - BBF needs to study further to clarify the set of issues associated with the Home LAN. This is purely informational at this point to identify the potential set of issues to be addressed.

6.9 Key Issue 9: IPTV and Multicast

IPTV is a key service part of fixed residential multi-play offerings. It is necessary to support IPTV service in 5G FMC architecture. Multicast is used to optimize network and video server resource usage, where the video client application (e.g. on a set-top box) requests live video content based on IGMP requests. Video packet replication happens on intermediate network elements (such as backbone routers, edge gateways, access nodes, RGs,...) to minimize the number of flows for a given channel / multicast group. There are several aspects that need to be considered:

Consider the criteria to developing the IPTV multicast solution:

1. How do we minimize the changes on 5G systems under the constraint of leveraging the widely deployed IPTV multicast functions on video client applications, RG and wireline access nodes, as described in TR-101 section 6?
2. Do we need the same IPTV multicast solution for both Integration model (wireline access) and FWA model?

Consider the technical issue to developing the IPTV multicast solution:

3. Study the Session Management mechanism to support IPTV multicast. Specifically, do we need an independent PDU session to transmit IPTV multicast packets? Or subdivide the PDU session to transmit the IPTV multicast packets? Or any other Session Management mechanism to support IPTV multicast?
4. Study if there is an option to offer multicast based IPTV service, in the case where the 5GC does not support multicast? In that case, how would IGMP/MLD (Multicast Listener Discovery, in the case of IPv6) messages be processed?
5. Study which network element (UPF, 5G-RAN, AGF and Wireline AN) is the best entity to perform the replication function? If the 5GC is involved in replication, does SMF need to be involved in multicast control plane (for example, IGMP/MLD processing)?
6. How to handle the QoS management for the IPTV Service? Can bandwidth and prioritization be adjusted dynamically for unicast traffic, depending on IPTV multicast traffic? Is there a way to do multicast admission control?
 - For context, dynamic QoS adjustment is done in order to avoid carving out bandwidth for IPTV traffic, so that the bandwidth can be reused by other services, in case no IPTV is in use. Based on the awareness of how many multicast groups are active on a subscriber line (eg, the home is currently receiving 2 HD TV streams at 8Mbps each), bandwidth for other services is dynamically modified. This link between multicast activity and QoS management is described in section 6.3 of TR-101i2.

Key Issue #9 Status - BBF needs to study further to clarify this key issue. BBF requires more information from 3GPP about multicast support in the 5GC and RAN.

6.10 Key Issue 10: Network Slice Selection

End to end slicing is being covered in detail in SD-406, which is work in progress at BBF, but this Section outlines the issues associated with Slice Selection that are relevant to this 5G FMC study.

Part of this involves the concept of a Slice Attachment Session which is the period of time during which an application or device is connected to, and able to use, the capabilities of a given slice. This is a generic term at this stage. The relationship between Slice Attachment Sessions and PDU sessions has yet to be determined; it remains to be seen if the two constructs can be made one and the same.

There is a significant business and Customer Experience element in these issues. In order to understand these, it is necessary to define 3 business entities:

The **Slice Provider** administers the infrastructure (which can of course include both wireless and virtualised elements) that provide the connectivity, performance and functionality for a number of different virtual networks.

The **Slice Buyer** purchases a virtual network slice from the Slice Provider in order to support the connectivity, performance and functionality needed for an industry vertical, or particular application.

The **Slice User** is the application or end-device that connects to, and uses the capabilities of, a particular slice.

When all 3 parties above are involved, it is essentially a wholesale model, but there is nothing to prevent a Slice Provider dealing directly with Slice Users if he so chooses.

Note that the end-device can be a 3GPP UE but it is not limited to being one. Slice attachment may well be applicable to other device types, both wireless and wireline, for example RGs, tablets, laptops, PCs, STBs, and IOT devices. The generic term (end-)device is therefore used instead of UE.

The Vanilla Slice corresponds to today's basic connectivity, typically to the Internet, which has no associated performance parameters or SLAs. Note that if the Vanilla Slice provides sufficient capability for the application/service, there is no incentive to pay more for a special slice.

The following questions are issues related to slice selection:

1. How are slices described ?

Slices need to be described in 2 different ways.

The Slice Buyer needs the slice to be described in a way that can be used as the basis for an SLA, and includes aspects of the Slice in its entirety, e.g. geographic coverage, number of attached/active end points, overall performance (e.g. aggregate bandwidth), functions supported etc. as well as the per connection performance. A lot of these will be parameterised, and can be subject to negotiation, which will at least be partly commercial.

The Slice User just needs to know which Slice Type is needed for a given application. This will probably be linked to the application/end-device, and so there is less need for this to be parameterised.

2. How are slices requested ?

The Slice Buyer will specify and request a Slice as part of a commercial negotiation with the Slice Provider.

The Slice User will not explicitly request a Slice, attachment to a Slice will usually be linked to an application/end-device.

3. Are Slice Types negotiable ?

The Slice Buyer will of course negotiate the nature of the slice, parameters of the slice and commercial arrangements with the Slice Provider.

The Slice User application/end-device needs to request connection to a Slice. This request must be able to be rejected, if the Slice Types is not supported, or there is insufficient capacity/resource to deliver the required performance/functionality. While this rejection needs to be communicated to the application/user, there is no requirement for negotiation (too complicated), although there is nothing to prevent the application requesting a different Slice Type in this event.

There needs to be the option to connect to the Vanilla Slice in the event of attachment rejection, but this will be application/end-device dependent, and in some cases may be risky, e.g. not getting the expected security features of the requested slice.

4. Is Slice Attachment session based, or done by end-device configuration ?

Slice attachment sessions allow better utilisation of network resources, and facilitate flexible charging based on:

- Attachment and/or

- Duration and/or
- Data volume

Multi-function devices must be able to support multiple, concurrent Sessions.

Session establishment/tear-down need to be able to be linked to applications/services.

Existing Multi-function devices (e.g. Smartphones) should automatically connect to the Vanilla slice on registration to avoid users losing their current expectation of connectivity. However such default connectivity may not be appropriate for new multi-function devices (e.g. a car), where connecting to the correct set of slices from the outset is very important.

Sessions should be able to support both time and volume based charging.

Sessions should be able to be requested at any time after device registration, not just at registration time.

Individual sessions should be able to be terminated before the device deregisters, but deregistration must automatically terminate all the sessions associated with that device.

A denied session request should only result in default connection to the Vanilla slice if there is some user benefit in so doing, and no danger of a key functionality being missing.

There should be support for simple devices that require permanent connection to a Slice, although this could be done by a session of indefinite duration,

A device entering a visited network should only request slice sessions for active or activated applications.

It should be possible to do performance monitoring on a per Session basis.

5. How does the end-device know which slice(s) it needs ?

Via the application or device type.

6. How are Slices linked to applications ?

The Slice capability needs to be advertised in such a way that the application writer/device manufacturer can determine if they need such defined capability (as opposed to basic connectivity).

7. How does the application/end-device know which slices are available ?

It doesn't actually need to. The application requests the necessary Slice, and the request is simply granted or denied.

8. Can an end-device connect to multiple slices?

This is an essential requirement. If the number of attachments is limited, the limit should be fairly high.

9. Who pays for the slices, and how ?

The Slice Buyer pays the Slice Provider for usage of the Slice.

The Slice User will generally have no awareness of the slice, and the cost of using it needs to be bundled with the application or service.

10. Is per Slice authorisation needed ?

Yes, this could either be done at Session attachment time or initial registration.

Key Issue #10 Status - BBF requires more information from 3GPP about Network Slice Selection.

6.11 Key Issue 11: QoS

Today wireline networks do not have the equivalent of bearers and QCI/ARP concepts. Instead QoS is based on hierarchical scheduling at the service edge and Diffserv/DSCP or 802.1p/P-bits in the rest of the access network.

Going forward with the 5GC, delivering Quality of Experience for wireline subscribers requires some adaptation on the to integrate with the QoS delivered by the 5GC.

This study will require to evaluate:

- Which wireline functions need to support 3GPP QoS concepts?
- Is there a need to mediate between legacy wireline QoS and 3GPP QoS, similar to requirements related to TWAG in TR-291? If yes, in which functions and does it impact only the user plane or also the data plane?

Key Issue #11 Status - BBF is still working on this key issue.

7 Direct Connect Model: Integration and Fixed Wireless Access

7.1 Architecture and Components

7.1.1 Integration Model

In this model, the converged 5G core network is used to deliver functions traditionally offered by the wireline core network. This model assumes some modifications to the Residential Gateway (5G RG) and a new function to mediate between the wireline access network and the converged core network, called 5G Access Gateway Function (5G AGF).

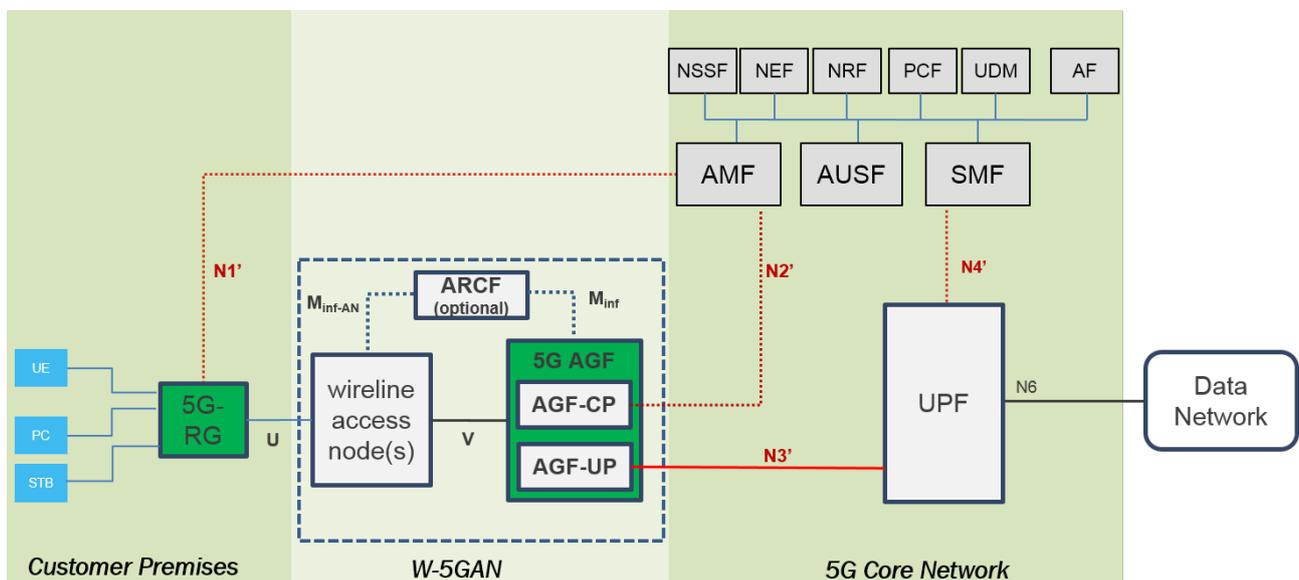


Figure 7-1. Integration model for wireline access

The egress interfaces of a W-5GAN form the border between access and core. They are N2' for the control plane and N3' for the user plane.

N1', N2', N3', N4' naming indicates that support of N1, N2, N3, N4 interface is currently under study. Whether different protocols, information models or procedures need to be supported will be a result of this study.

In this scenario, there is no NG-RAN connecting the 5G-RG which is only connected via wireline access. The user devices (i.e. UE, PC, and STB) access to the 5G Core Network (5GC) through 5G-RG and W-5GAN. N1' is supported by 5G-RG and carried over the W-5GAN. W-5GAN comprises of wireline access nodes (legacy) and an adaption function for 5G convergence, i.e. 5G AGF. The 5G AGF may be split into AGF-CP and AGF-UP, which support N2' and N3' to interact with AMF and UPF in the control plane and data plane, respectively.

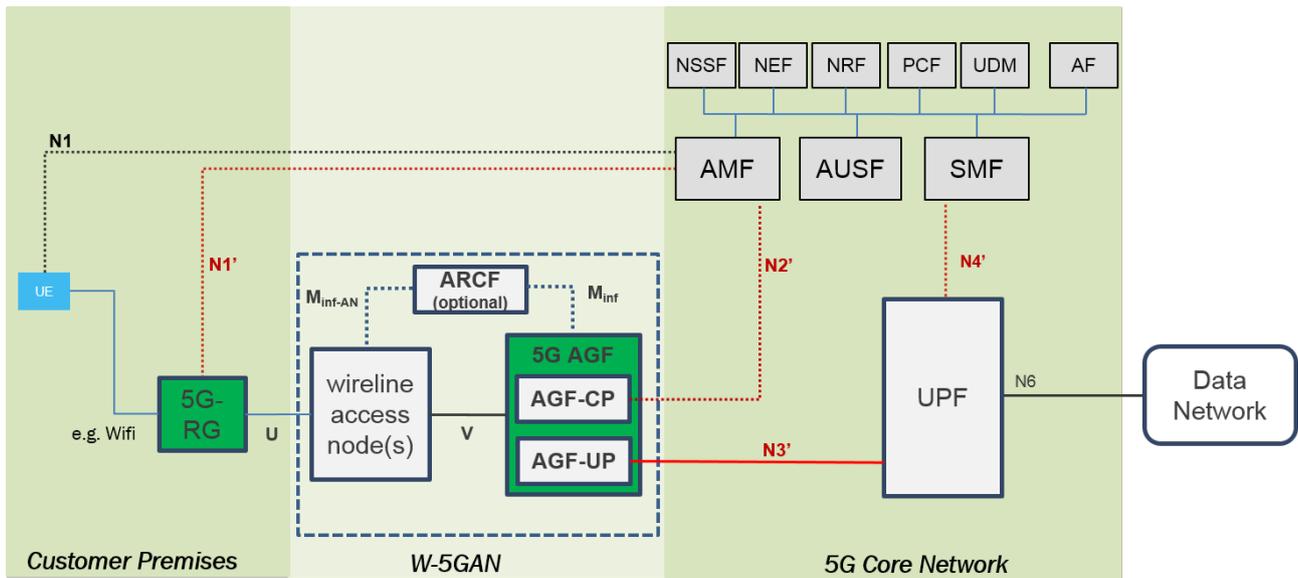


Figure 7-2. Integration model for wireline access - UE with N1 interface

In this scenario, the 5G-RG and the W-5GAN are connected to 5GC and UPF as in figure 5.1. The UE (e.g. a 3GPP UE or a 3GPP IoT) has its own N1 interface towards the 5G CN, and it accesses via 5G-RG and W-5GAN to 5GC. The N1 of UE is carried over the 5G-RG and W-5GAN towards the AMF in the 5GC.

Editor's Note: how the N1 of UE is carried towards the AMF is for further study.

7.1.2 Standalone Model: Fixed Wireless Access

In this model, the 5G core network is used to provide fixed broadband services. The residential gateway is a fixed wireless device accessing the wireless access network.

Editor's note: In this architecture, the BNG can be used as an option to provide both SMF and UPF functions which is an investment protection on both existing and future BNG deployment.

This section focuses on the case where FWA is provided by New Radio, connected to a 5G Core Network. Initial deployments of 5G FWA may be based on a 4G core network (non standalone mode), with an architecture similar to hybrid access as defined by TR-348, limited to a single, wireless link; however this is not in scope of this study document.

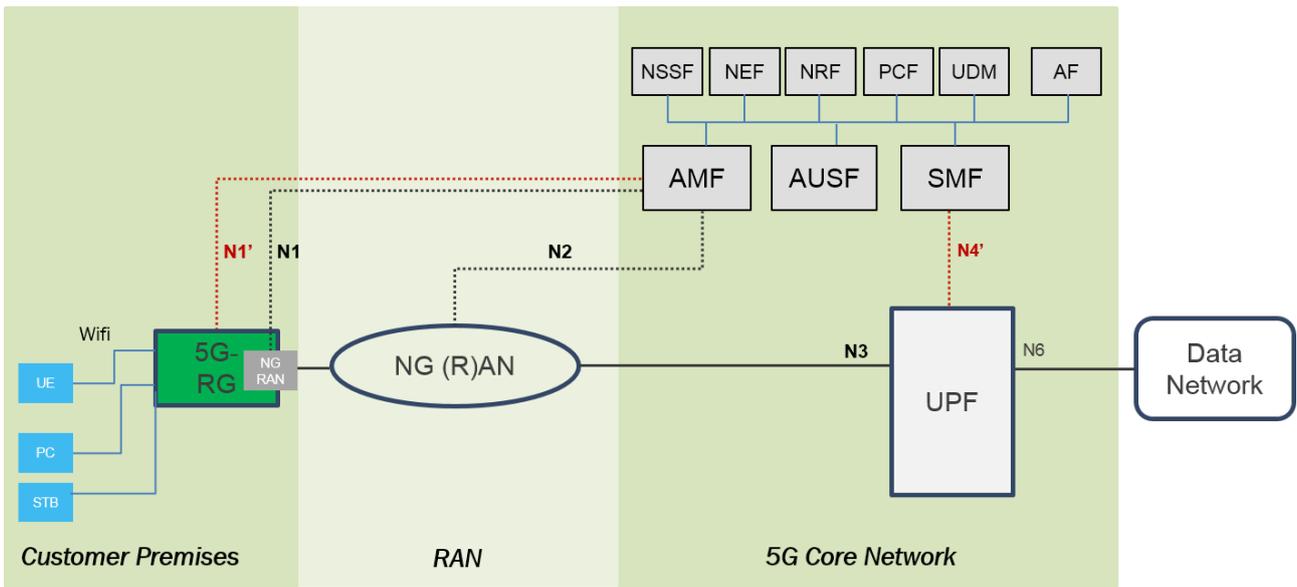


Figure 7-3 Fixed Wireless Access

7.2 Proposed Solutions

This is out of scope for this revision and will be added in a later version of this document.

7.2.1 Solution for Key Issue 1: Registration and Connection Management Procedures

7.2.2 Solution for Key Issue 2: Transport and Encapsulation in the Wireline Access of Control Plane (eg. NAS) and User Plane Traffic Exchanged with the 5G Core

7.2.3 Solution for Key Issue 3: Regulatory Requirements

7.2.4 Solution for Key Issue 4: Operational Requirements

7.2.5 Solution for Key Issue 5: Resource Management in the Access

7.2.6 Solution for Key Issue 6: Session Management

7.2.7 Solution for Key Issue 7: Addressing for IPv4 and IPv6

7.2.8 Solution for Key Issue 8: Home LAN Support

7.2.9 Solution for Key Issue 9: IPTV and Multicast

7.2.10 Solution for Key Issue 10: Network Slice Selection

7.2.11 Solution for Key Issue 11: QoS

7.3 Gap Analysis with 3GPP R15

This is out of scope for this revision and will be added in a later version of this document.

7.3.1 Functions

7.3.2 Interfaces

7.3.3 Procedures

8 Interworking

This is out of scope for this revision and will be added in a later version of this document.

9 Hybrid Access

This is out of scope for this revision and will be added in a later version of this document.

10 Summary - Recommendations

This is out of scope for this revision and will be added in a later version of this document.

End of Broadband Forum Study Document SD-420