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Abstract: This TD contains the final baseline text of the draft Recommendation ITU-T Q.4073 (Q.FW-IVV5G) "Framework for interconnection testing of Voice, Video over 5G" which was discussed and proposed for consent at the SG11 meeting (Geneva, 1-10 May 2024).

Draft Recommendation ITU-T Q.4073 (Q.FW-IVV5G)

Framework for interconnection testing of Voice, Video over 5G

1 Scope

This recommendation outlines the testing framework and procedures that operators should implement to establish interconnection between Voice over New Radio (VoNR) networks and to achieve worldwide interoperability with legacy and IMS/MMTel networks.

Both Voice over LTE (VoLTE) and Voice over New Radio (VoNR) use the same IP Multimedia Subsystem (IMS) framework as defined in ETSI. While the IMS framework remains the same, technological advancements in radio, core, and devices are expected to enhance user experience in VoNR compared to VoLTE. Therefore, the VoLTE end-to-end (E2E) scenarios for interconnection and roaming, as described in ITU-T Q.3640, are still applicable.

In addition, this recommendation identifies specific scenarios and requirements for VoNR interconnection and roaming, including possible E2E scenarios, a list of mandatory and optional services that operators should support for interconnection and roaming scenarios, a comparison between VoLTE/VoNR and EPSFB, and a protocol implementation statement (PICS) needed for the service level agreement (SLA).

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ETSI TS 123 501] ETSI TS 123 501 V17.11.0 (2024-01) 5G; System architecture for the 5G System (5GS) (ETSI TS 23.501 version 17.11.0 Release 17)

[ETSI TS 123 502] ETSI TS 123 502 V17.11.0 (2024-01). 5G;. Procedures for the 5G System. (3GPP TS 23.502 version 17.11.0 Release 17).

[ETSI TS 123 503] ETSI TS 123 503 V17.6.0 (2022-09). 5G;. Policy and charging control framework for the 5G System (5GS);. Stage 2. (3GPP TS 23.503 version 17.6.0 Release 17).

[ETSI TS 138 521-1] ETSI TS 138 521-1 V17.11.0 (2024-01): " NR; User Equipment (UE) conformance specification; Radio transmission and reception;. Part 1: Range 1 Standalone" (3GPP TS 38.521-1 version 17.11.0 Release 17)

[ETSI TS 138 521-2] ETSI TS 138 521-2 V17.5.0 (2024-01), 5G; NR; User Equipment (UE) conformance specification; Radio transmission and reception; Part 2: Range 2 standalone (3GPP TS 38.521-2 version 17.5.0 Release 17)

[ETSI TS 138 521-3] ETSI TS 138 521-3 V17.11.0 (2024-01)5G; NR; User Equipment (UE) conformance specification; Radio transmission and reception; Part 3: Range

1 and Range 2 Interworking operation with other radios (3GPP TS 38.521-3 version 17.11.0 Release 17)

[ETSI TS 138 521-4] ETSI TS 138 521-4 V17.5.0 (2024-01) 5G; NR; User Equipment (UE) conformance specification; Radio transmission and reception; Part 4: Performance (3GPP TS 38.521-4 version 17.5.0 Release 17)

[ETSI TS 138 521-5] ETSI TS 138 521-5 V17.0.0 (2024-01), 5G; NR; User Equipment (UE) conformance specification; Radio transmission and reception; Part 5: Satellite access Radio Frequency (RF) and performance (3GPP TS 38.521-5 version 17.0.0 Release 17)

[ETSI TS 138 523-1] ETSI TS 138 523-1 V17.5.1 (2024-02). 5G;. 5GS;. User Equipment (UE) conformance specification;. Part 1: Protocol. (3GPP TS 38.523-1 version 17.5.1 Release 17)

[ETSI TS 138 523-2] ETSI TS 138 523-2 V17.5.0 (2024-01) LTE; 5G; 5GS; User Equipment (UE) conformance specification; Part 2: Applicability of protocol test cases (3GPP TS 38.523-2 version 17.5.0 Release 17)

[ETSI TS 138 523-3] ETSI TS 138 523-3 V17.9.0 (2024-01), 5G; LTE; 5GS; User Equipment (UE) conformance specification; Part 3: Protocol Test Suites (3GPP TS 38.523-3 version 17.9.0 Release 17)

[ETSI TS 134 229-5] ETSI TS 134 229-5 V16.9.0 (2024-01) 5G; Internet Protocol (IP) multimedia call control protocol based on Session Initiation Protocol (SIP) and Session Description Protocol (SDP); User Equipment (UE) conformance specification; Part 5: Protocol conformance specification using 5G System (5GS) (3GPP TS 34.229-5 version 16.9.0 Release 16)

[ETSI TS 138 533] ETSI TS 138 533 V17.9.0 (2024-01). 5G;. NR;. User Equipment (UE) conformance specification;. Radio Resource Management (RRM). (3GPP TS 38.533 version 17.9.0 Release 17)

[ITU-T E.164] ITU-T E.164: "The international public telecommunication numbering plan"

[ETSI TS 103 653-1] ETSI TS 103 653-1 V2.1.1 (2022-01) Core Network and Interoperability Testing (INT); VoLTE/ViLTE interoperability test description over 4G/early 5G in physical/virtual environments; (3GPP™ Release 15); Part 1: Test Purposes (TP) and Protocol Implementation Conformance Statement (PICS) for VoLTE/ViLTE interoperability

[ETSI TS 103 653-2] ETSI TS 103 653-2 V2.1.1 (2022-01)Core Network and Interoperability Testing (INT); VoLTE/ViLTE interoperability test description over 4G/early 5G in physical/virtual environments; (3GPP™ Release 15); Part 2: Test Descriptions for VoLTE/ViLTE interoperability

[ETSI TS 123 216] ETSI TS 123 216 V17.1.0 (2022-07) Digital cellular telecommunications system (Phase 2+) (GSM); Universal Mobile Telecommunications System (UMTS); LTE; Single Radio Voice Call Continuity (SRVCC); Stage 2 (3GPP TS 23.216 version 17.1.0 Release 17)

[ITU-T Q.3640] ITU-T Q.3640: Framework of interconnection of VoLTE/ViLTE-based networks

[ITU-T Q.3953] ITU-T Q.3953: VoLTE/ViLTE interconnection testing for interworking and roaming scenarios

3 Definitions

None.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

5G	5th Generation (of mobile networks)
AI	artificial intelligence
AMF	Access and Mobility Management Function
AUSF	Authentication Server Function
CNNs	convolutional neural networks
DN	Data Network, e.g. operator services, Internet access or 3rd party services.
EIR	Equipment Identity Register
EN-DC	Evolved-Universal Terrestrial Radio Access-New Radio
ENUM	telephone Number Mapping
HPMN	Home Public Mobile Network
IMS	IP Multimedia Subsystem
IP	Internet Protocol
LBO	Local Breakout
LI	Lawful Interception
LTE	Long-Term Evolution
MMTel:	Multimedia Telephony
NEF	Network Exposure Function
NRF	Network Repository Function
NRF	Network Repository Function
NSACF	Network Slice Admission Control Function.
NSSAAF	Network Slice-specific and SNPN Authentication and Authorization Function ().
NSSF	Network Slice Selection Function
OTT	Over The Top
OTT	over-the-top
PCF	Policy Control Function
PS	Packet Switched
RAT	Radio Access Technology
SAE	System Architecture Evolution
SBA	Service-Based Architecture
SIP	Session Initiation Protocol

SLA	Service Level Agreement
SMF	Session Management Function
SMSF	SMS Function
UCMF	UE radio Capability Management Function
UDM	Unified Data Management
UDR	Unified Data Repository
UDSF	Unstructured Data Storage Function
UDSF	Unstructured Data Storage Function
UPF	User Plane Function ()
ViLTE	Video over LTE
ViNR	Video over New Radio
VoLTE	Voice over LTE
VoNR	Voice over New Radio
VoPS	IMS voice over PS Session
VPMN	Visited Public Mobile Network

5 Conventions

The following text refers to 5G as "IMT-2020" (International Mobile Telecommunications-2020). IMT-2020 encompasses a set of requirements and specifications for fifth-generation (5G) mobile networks, including maximum data transfer rates, latency, spectrum efficiency, and other factors.

The following text refers to LTE (Long-Term Evolution) as part of "IMT-Advanced" (International Mobile Telecommunications Advanced). IMT-Advanced is an international standard for mobile telecommunications technology defined by the ITU, encompassing a set of requirements and specifications for advanced mobile networks, including LTE.

6 Rationale

5G is a widely used wireless technology that provides customers access to IP core networks. By leveraging broadband wireless technology, such as 5G, telecommunication operators have achieved the concept of "all over IP networks" and can offer any telecommunication service through a wireless interface using an all-IP environment.

VoNR (Voice over New Radio) and ViNR (Video over New Radio) are commonly used to provide real-time voice and video services (e.g., telephony) through 5G networks. However, implementing VoNR presents challenges to operators who aim to establish end-to-end connections between calling parties. This is because there is only a packet-switched (PS) network and service control is provided by an IP multimedia subsystem (IMS).

Various VoNR solutions are available for operators, but these solutions are not always interoperable, and VoNR roaming procedures are not agreed upon, making them difficult to implement.

This recommendation outlines the testing framework and procedures that operators should implement to establish interconnection between Voice over New Radio (VoNR) networks and to achieve worldwide interoperability with legacy and IMS/MMTel networks.

7 Key issues of interconnection

There are several key issues related to interconnecting VoNR-based networks, including:

- Different options for signaling protocols used for Inter-IMS interconnection that can support all existing services, including basic call and supplementary services.
- Different options for roaming scenarios, as there are no strict requirements for operators and no default option.
- Charging issues, such as roaming charges and calls using interconnection networks.
- Numbering and addressing, which includes ENUM resolution and ITU-T E.164 to SIP-URI conversion.
- Floating delay, which involves providing legacy services and applications like Fax/Modem over IP.
- Lawful interception for compliance with legal requirements.
- Data retention for record-keeping purposes.
- Emergency services, including emergency call 112.

8 General principles of interconnection of VoNR-based networks

General principles of interconnection of VoNR-based networks

Voice over 5G (VoNR) and Voice over IP (VoIP) services are designed to provide voice services over packet-based networks, including 5G technology, on the access stratum. This allows traditional fixed or mobile telecommunication operators who have implemented 5G technology as an access technology to their core IP network to offer VoNR and VoIP services.

VoNR and VoIP services are considered "managed" voice services, which rely on standardized SIP/IMS signaling and are provided by telecommunication operators. In contrast, over-the-top (OTT) applications are services provided over the public internet by independent third parties, without standardized signaling protocols, traffic prioritization, or guaranteed quality of service.

An IMS platform serves as a service control stratum for managing VoNR and VoIP sessions. It provides services such as call control, media processing, QoS management, and charging. The IMS platform ensures seamless interconnection between different access networks and interoperability between different telecommunication operators. IMS also supports the delivery of other multimedia services, such as video and messaging, in addition to voice services.

VoNR and VoIP services represent a crucial application of 5G technology in delivering high-quality, managed voice services over packet-based networks. The use of standardized SIP/IMS signaling and the IMS platform ensures seamless interconnection between different networks and telecommunication operators, providing a consistent user experience for voice services.

Figure 1 depicts the reference architecture of the 5G System Architecture.

VoNR interconnection refers to the interconnection of IMS platforms for providing VoNR and legacy end-to-end sessions. There are two types of interconnection between IMS-based telecommunication operators:

1. Interconnection for delivering sessions among users of different operators, also known as interworking scenarios.
2. Interconnection for providing roaming of users of home networks in visited networks, also known as roaming scenarios.

There are also options for interconnection between VoNR and IMS-based networks with existing legacy networks, such as the Public Switched Telephone Network (PSTN) and the Public Land Mobile Network (PLMN).

To resolve ITU-T E.164 addresses to SIP URI, all IMS nodes can use the ENUM/DNS translation mechanism specified in [IETF RFC 3761]. Subsequently, the GSMA has published [GSMA PRD IR.67] and [GSMA PRD NG.105] to provide additional guidance on interconnection between IMS-based networks and VoNR networks.

It is important to note that Voice over IP (VoIP) and Voice over New Radio (VoNR) are two separate services. VoIP refers to voice services over IP networks, including the internet, while VoNR refers specifically to voice services over 5G networks.

Furthermore, to enable VoNR and VoIP interconnection between different telecommunication operators, various standardization bodies have defined specifications and guidelines for testing and validating the compatibility of equipment and networks. These specifications include the GSMA IR.92 and IR.51 for VoLTE (Voice over LTE) and the ETSI TS 123 503 for VoNR.

Overall, VoNR and VoIP services are critical components of 5G networks and are expected to play a key role in the delivery of high-quality voice

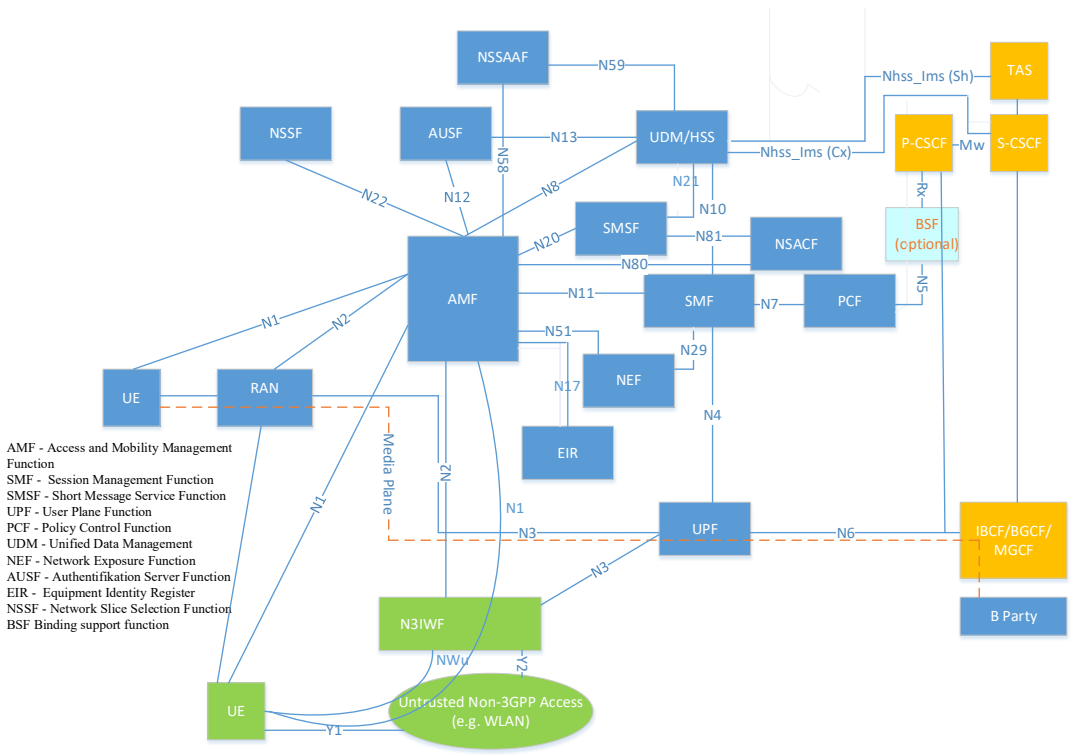


Figure 1: Non-Roaming **5G System** Architecture in reference point representation

9 E2E scenarios in terms of interconnection and roaming

9.1 According to general principles, the following are the key end-to-end (e2e) scenarios for VoNR interconnection:

Interworking scenarios for established connections: These scenarios involve interconnection between IMS platforms of different operators to deliver sessions among users of different networks.

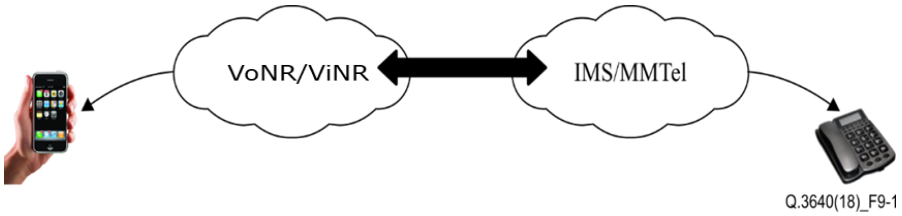


Figure 2 – VoNR – IMS/MMTel interconnection scenarios

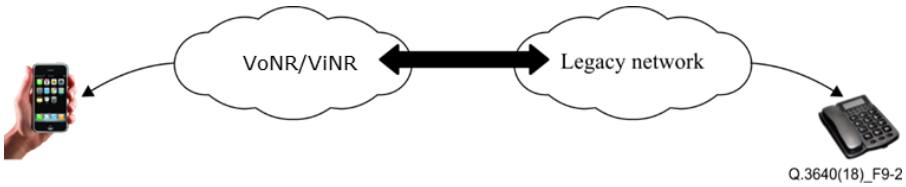


Figure 3 – VoNR – Legacy network interconnection scenarios

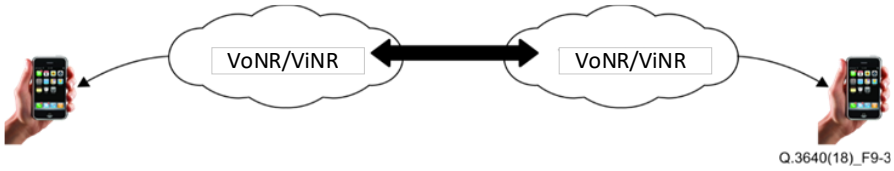
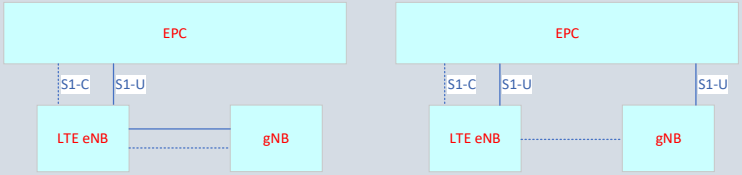


Figure 4 – VoNR – VoNR interconnection scenarios

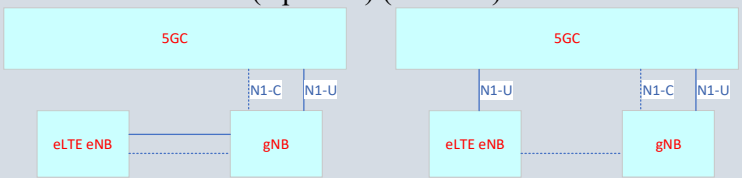
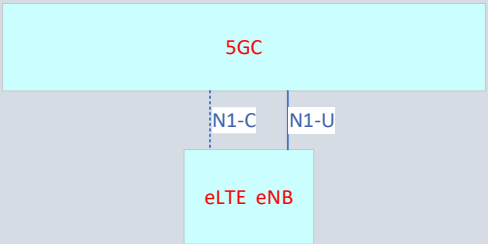
Table 1 – Definition of 5G access networks in terms of interconnection and roaming

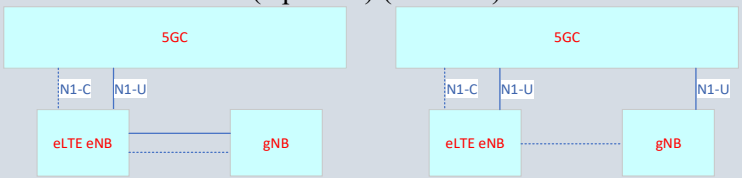
No.	Scenario	Description	Roaming options
Support of non-3GPP access			
1	1.1	Untrusted non-3GPP access networks;	
2	1.2	Trusted non-3GPP access networks;	
3	1.3	Wireline access networks.	
Trusted and Untrusted Non-3GPP Accesses			
Non-roaming			
4	1.1.1	Non-roaming architecture for 5G Core Network with untrusted non-3GPP access (ETSI TS 123 501 Chapter 4.2.8.2.1, Figure 4.2.8.2.1-1)	
5	1.1.2	Non-roaming architecture for 5G Core Network with trusted non-3GPP access	
6	1.1.3	5GC	LBO Roaming for 5G Core Network with untrusted non-3GPP access - N3IWF in the same VPLMN as 3GPP access (ETSI TS 123 501 Chapter 4.2.8.2.2, Figure 4.2.8.2.2-1)
7	1.1.4	5GC	LBO Roaming for 5G Core Network with untrusted non-3GPP access - N3IWF in a different PLMN from 3GPP access (ETSI TS 123 501 Chapter 4.2.8.2.2, Figure 4.2.8.2.2-2)
8	1.1.5	5GC	LBO Roaming for 5G Core Network with trusted non-3GPP access using the same VPLMN as 3GPP access (ETSI TS 123 501 Chapter 4.2.8.2.2, Figure 4.2.8.2.2-3)
9	1.1.6	5GC	LBO Roaming for 5G Core Network with trusted non-3GPP access using a different PLMN than 3GPP access (ETSI TS 123 501 Chapter 4.2.8.2.2, Figure 4.2.8.2.2-4)
Home-routed Roaming			
10	1.1.7	5GC	HR Roaming for 5G Core Network with untrusted non-3GPP access - N3IWF in the same VPLMN as 3GPP access

No.	Scenario	Description	Roaming options
			(ETSI TS 123 501 Chapter 4.2.8.2.3, Figure 4.2.8.2.3-1)
11	1.1.8	5GC	HR Roaming for 5G Core Network with untrusted non-3GPP access - N3IWF in a different VPLMN than 3GPP access (ETSI TS 123 501 Chapter 4.2.8.2.3, Figure 4.2.8.2.3-2)
12	1.1.9	5GC	HR Roaming for 5G Core Network with untrusted non-3GPP access - N3IWF in HPLMN (ETSI TS 123 501 Chapter 4.2.8.2.3, Figure 4.2.8.2.3-3)
13	1.1.10	5GC	HR Roaming for 5G Core Network with trusted non-3GPP access using the same VPLMN as 3GPP access (ETSI TS 123 501 Chapter 4.2.8.2.3, Figure 4.2.8.2.3-4)
Support of Wireline Access			
Non- roaming architecture			
14	1.3.1	5G Core Network for 5G-RG with Wireline 5G Access network and NG RAN (ETSI TS 123 501 Chapter 4.2.8.2.4, Figure 4.2.8.2.4-1)	
15	1.3.2	5G Core Network for FN-RG with Wireline 5G Access network and NG RAN (ETSI TS 123 501 Chapter 4.2.8.2.4, Figure 4.2.8.2.4-2)	
Access to 5GC from devices that do not support 5GC NAS over WLAN access			
16	1.3.3	Non-roaming and LBO Roaming supporting 5GC access from N5CW devices (ETSI TS 123 501 Chapter 4.2.8.5.2,Figure 4.2.8.5.2-1:	
Interwofrking with EPC (ETSI TS 123 501 Chapter 4.3)			
Non-roaming scenarios (ETSI TS 123 501 Chapter 4.3.1)			
17	1.4.1	Non-roaming scenarios for interworking between 5GS and EPC/E-UTRAN (ETSI TS 123 501 Chapter 4.3., Figure 4.3.1-1)	
Roaming scenarioss			
18	1.4.2	Interworking between 5GS and EPC/E-UTRAN	Local breakout roaming for interworking between 5GS and EPC/E-UTRAN (ETSI TS 123 501 Chapter 4.3., Figure 4.3.2-1)

No.	Scenario	Description	Roaming options
19	1.4.3	Interworking between 5GS and EPC/E-UTRAN	Home-routed roaming architecture for interworking between 5GS and EPC/E-UTRAN (ETSI TS 123 501 Chapter 4.3., Figure 4.3.2-2)
Interworking between 5GC via non-3GPP access and E-UTRAN connected to EPC			
Non-roaming scenarioss			
20	1.5.1	Non-roaming for interworking between 5GC via non-3GPP access and EPC/E-UTRAN (ETSI TS 123 501 Chapter 4.3, Figure 4.3.3.1-1)	
Roaming architecture			
21	1.5.2	Interworking between 5GS and EPC/E-UTRAN	Local breakout roaming architecture for interworking between 5GC via non-3GPP access and EPC/E-UTRAN (ETSI TS 123 501 Chapter 4.3, Figure 4.3.3.2-1)
22	1.5.3	Interworking between 5GS and EPC/E-UTRAN	Home-routed roaming architecture for interworking between 5GC via non-3GPP access and EPC/E-UTRAN (ETSI TS 123 501 Chapter 4.3, Figure 4.3.3.2-2)
Interworking between ePDG connected to EPC and 5GS			
Non-roaming scenarioss			
23	1.6.1	Non-roaming scenarios for interworking between ePDG/EPC and 5GS (ETSI TS 123 501 Chapter 4.3, Figure 4.3.4.1-1)	
Roaming scenarios for interworking between ePDG/EPC and 5GS			
24	1.6.2	Interworking between ePDG/EPC and 5GS	Local breakout roaming for interworking between ePDG/EPC and 5GS (ETSI TS 123 501 Chapter 4.3, Figure 4.3.4.2-1)
25	1.6.3	Interworking between ePDG/EPC and 5GS	Home-routed roaming for interworking between ePDG/EPC and 5GS (ETSI TS 123 501 Chapter 4.3, Figure 4.3.4.2-2)
5G scenarios in terms of 5G-NR(EN-DC) Bearer Concept			
26	1.7.1	5G (NSA) VoLTE with EN-DC split-bearer (LTE upgrade to support EN-DC (Option 3)) NOTE 1 	The 3GPP standards related to roaming for 5G (NSA) VoLTE with EN-DC split-bearer are specified in the following documents: ETSI TS 123 501: "System Architecture for the 5G System; Stage 2" ETSI TS 123 502: "Procedures for the 5G System; Stage 2" ETSI TS 123 503: "Policy and Charging Control Framework for the 5G System; Stage 2"

No.	Scenario	Description	Roaming options
			These standards provide detailed technical specifications for the implementation of 5G (NSA) VoLTE with EN-DC split-bearer, including the network architecture, protocols, and procedures required to support roaming. The split-bearer feature of EN-DC allows the 5G NR and LTE networks to be used simultaneously for voice and data transmission. The VoLTE (Voice over LTE) allows for high-quality voice calls over the LTE network, and with the support of EN-DC split-bearer, users can continue to make VoLTE calls while utilizing both the 5G NR and LTE networks for improved coverage and capacity. Overall, 5G (NSA) VoLTE with EN-DC split-bearer (LTE upgrade to support EN-DC) supports roaming and enables users to take advantage of both 5G NR and LTE networks for voice and data
27	1.7.2	5G (NSA) VoLTE without EN-DC split-bearer (LTE upgrade to support EN-DC (Option 3)) NOTE 1	The 3GPP standards related to roaming for 5G (NSA) VoLTE with EN-DC split-bearer are specified in the following documents: ETSI TS 123 501: "System Architecture for the 5G System; Stage 2" ETSI TS 123 502: "Procedures for the 5G System; Stage 2" ETSI TS 123 503: "Policy and Charging Control Framework for the 5G System; Stage 2" These standards provide detailed technical specifications for the implementation of 5G (NSA) VoLTE with EN-DC split-bearer, including the network architecture, protocols, and procedures required to support roaming. The split-bearer feature of EN-DC allows the 5G NR and LTE networks to be used simultaneously for voice and data transmission. The VoLTE (Voice over LTE) allows for high-

No.	Scenario	Description	Roaming options
			quality voice calls over the LTE network, and with the support of EN-DC split-bearer, users can continue to make VoLTE calls while utilizing both the 5G NR and LTE networks for improved coverage and capacity. Overall, 5G (NSA) VoLTE with EN-DC split-bearer (LTE upgrade to support EN-DC) supports roaming and enables users to take advantage of both 5G NR and LTE networks for voice and data
28	1.7.3	5G Single Radio Voice Call Continuity (SRVCC)	5G Single Radio Voice Call Continuity (SRVCC) is described in the 3GPP technical specifications ETSI TS 123 501 chapter 5.4.4 "UE Radio Capability handling" and ETSI TS 123 216
	1.7.4	5G (NSA) circuit-switched fallback (CSFB) mode using 2G or 3G. NOTE 2:	
29	1.7.5	5G (NSA) eLTE-NR; Dual Connectivity with 5GC. In Option 4/4A, the gNB is connected to the NGC with Non-standalone E-UTRA. The E-UTRA user plane connection to the NGC goes via the gNB (Option 4) or directly (Option 4A) (Option 4) (NOTE 3) 	The 5G (NSA) eLTE-NR; Dual Connectivity with 5GC (Option 4) roaming is described in the ETSI TS 123 501 standard, which covers the System Architecture for the 5G System. Specifically, the details of the 5G (NSA) eLTE-NR; Dual Connectivity with 5GC (Option 4) roaming are provided in Chapter 5.2.2.5 of ETSI TS 123 501, which covers the interworking between the 5G System and LTE. Additionally, the details of the roaming are provided in Chapter 8.5, which covers the roaming architecture and procedures for the 5G System.
30	1.7.6	In Option 5, the eLTE eNB is connected to the NGC 	

No.	Scenario	Description	Roaming options
31	1.7.7	5G (NSA) NR-eLTE; Dual Connectivity (Option 7) (NOTE 4)  	The roaming of 5G (NSA) NR-eLTE; Dual Connectivity (Option 7) is described in the 3GPP ETSI TS 123 501 standard, Specifically, the details of the roaming are provided in Chapter 8.5, which covers the roaming architecture and procedures for the 5G System. Chapter 5.2.2.5 also provides some information on the interworking between the 5G System and LTE, which is relevant to Option 7 of the Dual Connectivity feature.

NOTE 1:
EN-DC (E-UTRA-NR Dual Connectivity) is a 5G technology that allows 5G devices to use both 4G LTE and 5G networks simultaneously. This technology improves network performance by enabling devices to use the best available connection for a given task, depending on factors such as network coverage, signal strength, and bandwidth requirements.
Split-bearer is a 5G technology that allows for the separation of data traffic between the 5G network and the 4G LTE network. It allows the 5G network to handle high-speed, low-latency traffic, while the 4G LTE network can handle slower-speed, high-latency traffic.
In the context of LTE upgrade to support EN-DC (Option 3), this refers to a specific configuration that allows for the use of both 4G LTE and 5G networks simultaneously. Option 3 involves using the E-UTRA (Evolved Universal Terrestrial Radio Access) as the anchor for both the 4G LTE and 5G networks. This enables devices to use both networks simultaneously, with the 4G LTE network acting as a secondary connection to support 5G data traffic.
Overall, the combination of 5G (NSA), VoLTE, and EN-DC split-bearer (LTE upgrade to support EN-DC (Option 3)) offers improved network performance, faster data speeds, and better call quality for users.
The main difference between 5G (NSA) VoLTE with EN-DC split-bearer and 5G (NSA) VoLTE without EN-DC split-bearer is in the way data traffic is handled between the 4G LTE and 5G networks.
In 5G (NSA) VoLTE with EN-DC split-bearer, the 5G network handles high-speed, low-latency traffic, while the 4G LTE network handles slower-speed, high-latency traffic. This is achieved through the use of split-bearer technology, which separates the data traffic between the 4G LTE and 5G networks.
In contrast, 5G (NSA) VoLTE without EN-DC split-bearer does not use split-bearer technology. Instead, it relies on the 5G network to handle all data traffic, including slower-speed, high-latency traffic that would typically be handled by the 4G LTE network. This can result in reduced network performance and slower data speeds, especially in areas where 5G coverage is limited or weak.
In summary, the key difference between the two is that 5G (NSA) VoLTE with EN-DC split-bearer uses split-bearer technology to enable both 4G LTE and 5G networks to handle data traffic simultaneously, while 5G (NSA) VoLTE without EN-DC split-bearer relies solely on the 5G network to handle all data traffic

In the Option 3 networking mode, the X2 interface traffic between eNB and gNB has NSA user plane traffic. This traffic is huge. The core network needs to increase the bandwidth of the S1-U interface to meet the LTE/NSA transmission requirements.
In the Option 3a networking mode, there is only control plane traffic in the X2 interface. So the X2 traffic is very small.
In the Option 3x networking mode, there is a little LTE user plane traffic in the X2 interface.
From the perspective of the impact on the existing network, the Option 3x is relatively small and has become the mainstream choice for NSA networking. By using 4G as the anchor point of the control plane, it can meet good service continuity and support rapid network construction in the initial stage of 5G deployment.

NOTE 2: 5G (NSA) circuit-switched fallback (CSFB) mode is a fallback mechanism used when a 5G device needs to make a voice call or send an SMS message. In this mode, the device falls back to the 2G or 3G network to complete the call or message.
The reason for this fallback is that 5G networks are primarily designed for data traffic, and there may be limitations in supporting voice and SMS traffic. As a result, when a voice call or SMS is made from a 5G device, the device falls back to the legacy 2G or 3G network to complete the transaction.
CSFB mode involves establishing a voice or SMS session on the 2G or 3G network while simultaneously maintaining a data session on the 5G network. This enables users to continue using their 5G device for data services while making a voice call or sending an SMS message.

One limitation of CSFB mode is that it can result in a delay in call setup time as the device switches from the 5G network to the 2G or 3G network. Additionally, the quality of the voice call or SMS message may be affected if the network signal is weak or if there is interference on the legacy network. Overall, CSFB mode is a fallback mechanism used by 5G (NSA) devices to enable voice and SMS services using the legacy 2G or 3G networks. While it may result in some limitations and delays, it ensures that users can continue to make voice calls and send SMS messages even when 5G network coverage is limited or weak.

NOTE 3: The eLTE network serves as an anchor for the 5G NR radio access network, allowing for faster deployment and a smoother transition to full 5G Standalone (SA) networks in the future. This architecture enables the deployment of 5G services while leveraging existing infrastructure and spectrum.

Dual connectivity with 5GC (5G Core) refers to the capability of devices to simultaneously connect to both the eLTE and 5G NR networks, while also being able to utilize the features and services of the 5G Core. This allows for improved data rates, lower latency, and better coverage and capacity.
Overall, 5G (NSA) eLTE-NR with dual connectivity to 5GC is a flexible and efficient way to introduce 5G capabilities into existing networks, while also providing a foundation for future expansion and innovation in 5G technology.

NOTE4: 5G (NSA) NR-eLTE dual connectivity, also known as Option 7, is a network architecture that combines Non-Standalone (NSA) 5G New Radio (NR) with an enhanced Long Term Evolution (eLTE) network. This architecture allows for the deployment of 5G services while leveraging existing infrastructure and spectrum, while also allowing devices to simultaneously connect to both networks.
In this architecture, the eLTE network serves as an anchor for the 5G NR radio access network, enabling faster deployment and a smoother transition to full 5G Standalone (SA) networks in the future. The 5G NR network provides the higher data rates, lower latency, and improved coverage and capacity that are characteristic of 5G technology.
Dual connectivity allows devices to simultaneously connect to both the eLTE and 5G NR networks, resulting in improved data rates and coverage. In addition, the 5G Core (5GC) can be utilized to provide advanced services and features, such as network slicing, which enables the creation of virtual networks with customized performance characteristics to meet specific use cases.

Overall, 5G (NSA) NR-eLTE dual connectivity (Option 7) is a flexible and efficient way to introduce 5G capabilities into existing networks, while also providing a foundation for future expansion and innovation in 5G technology.

9.2 Overview and Comparison of 5G connectivity options and IMS impacts

The fifth generation of wireless technology, 5G, provides significant improvements over its predecessors, including faster data rates, lower latency, and higher reliability. The three main connectivity options for 5G are standalone (SA), non-standalone (NSA), and dynamic spectrum sharing (DSS). Each has its own advantages and disadvantages, and the choice of which one to use depends on the specific needs of each operator.

Implementing 5G technology has a significant impact on IP multimedia subsystems (IMS), which are used for delivering voice and multimedia services over IP networks. 5G introduces new signaling procedures, such as registration and session establishment, which must be integrated with existing IMS procedures. To accommodate these changes, several IMS enhancements have been proposed, including enhanced service-based architecture (SBA), network slicing, and converged core network (CCN). These enhancements provide a more modular and scalable architecture for IMS, enable the creation of dedicated virtual networks for different services and applications, and simplify the overall network architecture.

9.2.1 Service-Based Architecture (SBA)

The SBA architecture for IMS offers a more scalable, flexible, and open approach to building communication networks. It enables operators to deploy and upgrade services quickly and easily, support a wide range of use cases and services, and offer customized services with different levels of performance and quality of service. As 5G networks continue to evolve and new services and applications emerge, the SBA-based IMS architecture is likely to play a key role in enabling the next generation of communication networks.

9.2.2 CNN Converged Core Network

Converged Core Network is a next-generation mobile network architecture that combines the power of 5G cellular networks and convolutional neural networks (CNNs) in the core network. The converged core network is designed to enable low-latency, high-speed connectivity with advanced features such as network slicing, edge computing, and artificial intelligence (AI) capabilities.

In a typical 5G network architecture, the core network is responsible for managing the overall network operations and providing advanced services such as network slicing, edge computing, and IoT connectivity. With the integration of CNNs into the core network, the converged network can provide enhanced capabilities such as real-time data analytics, predictive maintenance, and automated decision-making.

The 5G CNN converged core network leverages the power of machine learning to analyze massive amounts of data generated by the network, such as video streams, sensor data, and other forms of multimedia. The CNNs can then learn from this data to make predictions and provide insights that can be used to optimize network performance, improve user experience, and enhance security.

One of the key benefits of the 5G CNN converged core network is its ability to support network slicing, which allows operators to create multiple virtual networks with different characteristics for different use cases. This feature can be used to support mission-critical applications such as autonomous driving, remote surgery, and industrial automation, among others.

9.2.3 5G connectivity options

5G technology offers several connectivity options that enable high-speed data transfer and low-latency communication. These options are designed to support a variety of use cases, from enhanced mobile broadband to mission-critical communications. Here are some of the key 5G connectivity options:

Enhanced Mobile Broadband (eMBB): This is the most widely used 5G connectivity option, designed to provide high-speed data transfer to mobile devices, laptops, and other devices. With eMBB, users can enjoy faster download and upload speeds, smoother streaming of high-definition video, and better overall performance.

Ultra-Reliable Low-Latency Communications (URLLC): This connectivity option is designed for mission-critical applications that require extremely low latency and high reliability, such as autonomous vehicles, remote surgery, and industrial automation. With URLLC, devices can communicate with each other and with the network with latencies as low as a few milliseconds.

Massive Machine-Type Communications (mMTC): This connectivity option is designed for IoT devices and other devices that require low data rates and long battery life. With mMTC, devices can connect to the network using a narrowband connection that consumes very little power.

Network Slicing: This is a virtual network architecture that enables the creation of multiple logical networks on a shared physical network infrastructure. With network slicing, service providers can allocate network resources to different use cases based on their requirements, such as bandwidth, latency, and reliability.

Multi-Access Edge Computing (MEC): This is an architecture that brings computing resources closer to the network edge, enabling faster data processing and lower latency. With MEC, applications can be run on servers located near the end-user, rather than in a centralized data center, which can reduce latency and improve performance.

These 5G connectivity options provide a range of capabilities that enable a wide range of use cases, from consumer applications to mission-critical services. Service providers can choose the appropriate connectivity option based on the requirements of the use case, and can also combine multiple connectivity options to provide a more flexible and scalable network.

Dual connectivity is a technique used in mobile networks to provide simultaneous connectivity to two different radio access technologies (RATs). It has been widely used in LTE networks to provide better coverage and higher data rates to users. With the introduction of 5G, the concept of dual connectivity has evolved to include LTE/eLTE and NR (New Radio) as master or secondary RATs in different combinations.

In this new use case of dual connectivity, LTE/eLTE is used as the primary RAT, while NR is used as a secondary RAT to provide additional capacity and higher data rates. This approach is particularly useful in areas where 5G coverage is limited, or the deployment of 5G infrastructure is not feasible due to various reasons.

One of the key advantages of using dual connectivity with LTE/eLTE and NR is the ability to achieve higher data rates and better coverage. By combining the strengths of both technologies, users can enjoy seamless connectivity and faster data transfer rates. Additionally, this approach can also help network operators to leverage their existing LTE/eLTE infrastructure and gradually transition to 5G.

To implement this approach, network operators must ensure that their infrastructure is capable of supporting dual connectivity with LTE/eLTE and NR. This requires a scalable architecture that can support both technologies and allow for seamless switching between them. The introduction of 5G System Architecture (5G SA) and Service-Based Architecture (SBA) has made it easier to implement and manage dual connectivity in mobile networks.

Overall, the use of dual connectivity with LTE/eLTE and NR is a promising approach to provide better coverage and higher data rates to users in areas where 5G infrastructure is not yet available. With the continued evolution of 5G technology and the introduction of new use cases, dual connectivity is likely to play an increasingly important role in mobile networks.

Connectivity option	Core Network	Master RAT	Secondary RAT	ETSI term
Option 1	EPC	LTE		LTE
Option 2	5GC	NR	-	NR
Option 3	EPC	LTE	NR	EN-DC (Evolved-Universal Terrestrial Radio Access-New Radio)
Option 4	5GC	NR	eLTE	NE-DC (Evolved-Universal Terrestrial Radio Access-New Radio)
Option 5	5GC	eLTE	-	eLTE enhanced LTE (*eLTE*) eNB which can communicate with *5G* Core (5GC) and gNB
Option 7	5GC	eLTE	NR	NGEN-DC (NR for data only)

Table 2: 5G connectivity options

5G Standalone (SA) Option 2 is a deployment option in which the 5G core network is connected to the 5G radio access network (RAN) via an interface known as the NG interface. In this option, the 5G RAN is based on the 5G New Radio (NR) technology, while the core network is based on a Service-Based Architecture (SBA) that provides a modular and scalable framework for delivering various 5G services.

In SA Option 2, the user equipment (UE) is connected to the 5G RAN, which provides the radio connectivity for data and voice services. The 5G RAN is connected to the 5G core network through the NG interface, which provides the control and management functions for the 5G network.

SA Option 2 provides several benefits over other deployment options. For example, it provides a simplified network architecture, which reduces the complexity and cost of deploying and maintaining the 5G network. It also provides a high degree of flexibility, which allows operators to deploy 5G services more quickly and efficiently.

Option 3 EN-DC (Evolved-Universal Terrestrial Radio Access-New Radio) is a deployment option for 5G networks that combines both 4G LTE and 5G New Radio (NR) technologies. It is a Non-Standalone (NSA) architecture, which means it relies on the existing 4G LTE infrastructure to support 5G services. This deployment option is also known as E-UTRA-NR Dual Connectivity (EN-DC).

In Option 3 EN-DC, the 5G NR network is used for data transmission while the 4G LTE network is used for control signaling and for providing coverage in areas where 5G NR coverage is not yet available. This allows for a smoother transition from 4G to 5G as well as better coverage and capacity for the end-users.

In Option 3 EN-DC, the 5G NR connection can be used as either the master or secondary connection. When the 5G NR connection is used as the master connection, it provides the primary data path, and the 4G LTE connection is used for control signaling. When the 5G NR connection is used as the secondary connection, it provides additional capacity to the 4G LTE connection, which remains as the primary data path.

Option 3 EN-DC allows for a smooth transition from 4G to 5G by enabling devices to utilize both technologies simultaneously. This deployment option also allows operators to quickly deploy 5G services by leveraging their existing 4G LTE infrastructure. However, it does not provide the full benefits of a standalone 5G network, such as low latency and high bandwidth.

Option 4 is a 5G Standalone (SA) deployment that provides a complete end-to-end 5G solution. It includes both the 5G core network (5GC) and the 5G New Radio (NR) access network.

In Option 4, the 5GC and the NR access network are connected through the Next-Generation NodeB (NG-eNB), which is an upgraded version of the eNodeB used in LTE networks. The NG-eNB provides the radio access network for 5G devices and interfaces with the 5GC to provide connectivity to the core network and other services.

Option 4 represents the NE-DC (New Radio - Dual Connectivity) mode, which allows for simultaneous connection to both the 5G NR and LTE networks. This is achieved through the use of a multi-connectivity architecture that enables the device to connect to both the 5G NR and LTE networks simultaneously.

The NE-DC mode offers several benefits, such as seamless mobility between the two networks, better coverage and capacity, and improved user experience. It also enables the deployment of 5G services without disrupting existing LTE services.

Option 4 is particularly well-suited for applications that require low latency and high bandwidth, such as industrial IoT, augmented reality/virtual reality, and autonomous vehicles. It also provides a

platform for the development of new services and applications that leverage the capabilities of 5G networks.

Overall, Option 4 is a flexible and scalable deployment option that enables operators to provide a complete end-to-end 5G solution with a high degree of flexibility and performance.

5G Option 5, also known as Standalone (SA) 5G, is one of the connectivity options for 5G networks. It refers to a complete end-to-end 5G system that operates independently of existing 4G networks.

In SA 5G, the 5G core network and 5G radio access network (RAN) are both fully implemented, which enables the full benefits of 5G technology, such as ultra-low latency, network slicing, and enhanced mobile broadband services.

Compared to Non-Standalone (NSA) 5G, which relies on existing 4G infrastructure for some of its functions, SA 5G provides a more comprehensive and integrated 5G experience. However, SA 5G requires a higher level of investment and infrastructure, as it involves building a completely new network from scratch.

SA 5G is expected to be the standard for 5G networks in the future, as it provides the most advanced and efficient 5G connectivity, but it may take some time for operators to fully transition to this option.

5G Option 7 is a network architecture option for 5G networks that is defined by ETSI (the 3rd Generation Partnership Project).

In 5G Option 7, the 5G Core Network (5GC) is connected to the Evolved Packet Core (EPC) of the 4G LTE network. This enables the use of the existing EPC infrastructure for 5G services, allowing for a smoother transition to 5G.

One of the key features of 5G Option 7 is access traffic steering, switching and splitting (ATSSS), which enables the intelligent management of traffic between the 4G LTE and 5G networks. This allows for more efficient use of network resources and ensures that users are always connected to the best available network.

In addition, 5G Option 7 includes an integrated access and mobility management function (IAMF), which provides seamless mobility between 4G and 5G networks. This ensures that users can stay connected even when they move between different coverage areas.

Overall, 5G Option 7 is a cost-effective and efficient way to introduce 5G services while leveraging existing network infrastructure. It enables seamless connectivity between 4G and 5G networks, while providing the benefits of high-speed data rates, low latency, and improved reliability.

10 IMS Roaming, Interconnection and Interworking Guidelines [from GSMA PRD IR.65]

Roaming Guidelines for 5G are described in the GSMA PRD IR.65. Chapter 2A.2 outlines the IMS Roaming architecture for 5GS, while chapter 2.A.4 describes the requirements for the IMS roaming

architecture." The Official Document NG.113 - 5GS Roaming Guidelines aims to provide a standardised view on how 5G System (5GS) networks making use of the 5G Core (5GC) can interconnect and/or interwork when users roam onto a network different to their HPMN (Home Public Mobile Network). This will be applicable when NR (New Radio) radio bearers are used, connected to a 5GC, and both UE (user equipment) and VPMN (visited PMN) have matching capabilities. The main focus is to describe 5GC, NR and interworking with EPS during roaming.

11 Testing of mobile and legacy end-to-end (e2e) sessions

The ITU-T Q.3640 Recommendation “Framework of interconnection of VoLTE/ViLTE-based networks” describes the framework and procedures that should be implemented by operators for establishing an interconnection between voice over long-term evolution / video over long-term evolution (VoLTE/ViLTE)-based networks to achieve worldwide interoperability.

The Recommendation ITU-T Q.3953 aims to verify the roaming between Voice over LTE (VoLTE)/Video over LTE (ViLTE) networks, interoperability with legacy and IMS/MMTel networks, and service level agreements (SLAs) among operators.

The GSMA (GSM Association) has established a set of tests to verify the end-to-end (e2e) interconnection scenarios **between two mobile networks**. These tests are designed to ensure that the interconnection between two networks is functioning correctly, and that users can make and receive calls and messages across the two networks without any issues.

The document ETSI TS 103 653-2 provides the Test Descriptions (TDs) for the VoLTE/ViLTE interoperability test description over 4G/early 5G in physical/virtual environments in compliance with the relevant requirements and in accordance with the Test Purposes (TPs) presented in ETSI TS 103 653-1. Emergency call and enhanced eCall are not in scope of the document.

11.1 User Equipment (UE) conformance test specifications for 5G; LTE; 5GS

The UE conformance test specifications for 5G, LTE, and 5GS cover a wide range of testing requirements, including functional testing, performance testing, interoperability testing, and security testing. These specifications play a critical role in ensuring the quality and reliability of UEs and enabling the deployment of standardized and interoperable 5G networks.

The 5G UE conformance test specifications include:

1. ETSI TS 138 521: This specification is covering the New Radio (NR) User Equipment (UE) conformance specification. The present document is a multi-part deliverable as identified below:
   - 3GPP TS 38.521-1: " NR; User Equipment (UE) conformance specification; Radio transmission and reception; Part 1: Range 1 Standalone" (the present document).
   - 3GPP TS 38.521-2: " NR; User Equipment (UE) conformance specification; Radio transmission and reception; Part 2: Range 2 Standalone".
   - 3GPP TS 38.521-3: “NR; User Equipment (UE) conformance specification; Radio transmission and reception; Part 3: Range 1 and Range 2 Interworking operation with other radios” –
   3GPP TS 38.521-4: “NR; User Equipment (UE) conformance specification; Radio transmission and reception; Part 4: Performance”. -

2. ETSI TS 138 523: This specification defines the conformance test procedures for the 5G NR (New Radio) UE protocol and radio conformance. The present document is a multi-part deliverable as identified below:

- 3GPP TS 38.523-1: "5GS; User Equipment (UE) conformance specification; Part 1: Protocol" (the present document).
- 3GPP TS 38.523-2: "5GS; User Equipment (UE) conformance specification; Part 2: Applicability of protocol test cases".
- 3GPP TS 38.523-3: "5GS; User Equipment (UE) conformance specification; Part 3: Protocol Test Suites"

3. ETSI TS 138 533: This specification defines the conformance test procedures for the 5G NR UE radio frequency (RF) and radio resource management (RRM) conformance.

4. ETSI TS 134 229-5 5G; Internet Protocol (IP) multimedia call control protocol based on Session Initiation Protocol (SIP) and Session Description Protocol (SDP); User Equipment (UE) conformance specification; Part 5: Protocol conformance specification using 5G System (5GS) (3GPP TS 34.229-5 version 16.9.0 Release 16)

12. IMS Profile for Voice, Video and Messaging over 5GS [from GSMA NG.114]

The IP Multimedia Subsystem (IMS) Profile for voice, video and messaging, documented in the GSMA NG.114, defines a profile that identifies a minimum mandatory set of features which are defined in 3GPP and GSMA specifications that a wireless device (the User Equipment (UE)) and network are required to implement in order to guarantee interoperable, high quality IMS-based communication services for voice, video and messaging over NG (Next Generation) radio access connected to 5GC. The content includes the following aspects:

1. Basic capabilities and supplementary features for IMS-based communication services for voice, video and messaging.

2. IMS media negotiation, transport, and codecs.

3. Radio and packet core feature set.

4. Common functionalities that are relevant across the protocol stack and subsystems

5. Additional features that only a subset of the IMS telephony operators needs to support in certain regions.

6. UE configuration to provide all necessary information to connect to, and to receive service from, a specific IMS telephony and messaging operator.

7. Support for Unstructured Supplementary Service Data (USSD) Simulation Service in IMS (USSI) as optional feature.

The main body of the GSMA NG.114 is applicable for a scenario where IMS-based voice, video and messaging services are deployed in the 5G System (NG-RAN,5GC, and UE. In order to be fully compliant with this IMS Profile for voice, video and messaging, the UEs and networks must be compliant with all normative statements in the main body. Messaging related statements in this document apply to only those 5G UEs that support messaging. Messaging covered in this document includes both RCS (Rich Communication Suite) Messaging services and SMS (Short Message Service). The present version of this PRD is restricted to profiling related to NG-RAN option SA NR per the definition in ETSI TS 123 501.

Bibliography

[b-GSMA PRD IR.51] GSMA PRD IR.51, MS Profile for Voice, Video and SMS over Wi-Fi

[b-GSMA PRD IR.65] GSMA PRD IR.65, *IMS Roaming and Interworking Guidelines*.

[b-GSMA PRD IR.67] GSMA PRD IR.67, *DNS and ENUM guidelines for service providers and GRX and IPX providers*.

[b-GSMA PRD NG.105] GSMA PRD NG.105, *ENUM Guidelines for Service Providers and IPX Providers*.

[b-RFC 3761] RFC 3761 (2004), *The E.164 to Uniform Resource Identifiers (URI) Dynamic Delegation Discovery System (DDDS) Application (ENUM)*.

[b-GSMA's NG.114] IMS Profile for Voice, Video and Messaging over 5GS Version 1.0 07 August 2020

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