Vo5G Technical White Paper

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HUAWEI TECHNOLOGIES CO., LTD.

Huawei Technologies Co., Ltd.

Address: Huawei Industrial Base, Bantian, Longgang, Shenzhen 518129

                  People's Republic of China

Website: http://www.huawei.com

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1 Introduction

On June 14, 2018, 3GPP TSG #80 Plenary Meeting approved the completion of 5G NR specifications for standalone (SA). In addition, after the release of the 5G NR specifications for non-standalone (NSA) in December 2017, standardization of 5G at the first stage has been successfully completed. This means that 5G standards are completed on time and 5G networks will be put into commercial use.

Although data services drive 5G evolution, voice/video communication services are still important services of carriers. Like 4G networks, how to provide voice/video communication services must be first determined for 5G commercialization.

2 Vo5G Has Been Standardized Together with 5G

2.1 What Is Vo5G?

3GPP has specified that 5G uses the 4G voice/video communication architecture and still provides voice/ video communication services based on the IMS. The 4G radio access technology is LTE, and the voice/video over the LTE network is called VoLTE. The 5G radio access technology is NR, and the

voice/video over the 5G network is called voice/video over NR (VoNR). VoLTE and VoNR are different access modes for IMS voice/video communication services.

In the 4G voice solution, VoLTE is the target voice/video communication solution for 4G networks. With the expansion of 4G network coverage and maturity of the terminal ecosystem considered, global carriers have experienced the evolution from CSFB to VoLTE.

In addition to the expansion of 5G network coverage and maturity of the terminal ecosystem, carriers need to consider the factors of various 5G network deployment options when deploying 5G networks. The 5G voice/video communication solution faces the options and evolution process shown in the following figure.

	Introducing 5G by EPC NSA	Introducing 5G by 5GC			
	Option3/3a/3X	Option4/4a	Option7/7a/7X	Option 5	Option 2
Optional Voice/Video Communication Solution	CSFB->VoLTE->VoNR	EPS FB or RAT FB or VoLTE->VoNR	VoeLTE->VoNR	VoeLTE	EPS FB or RAT FB or VoLTE->VoNR
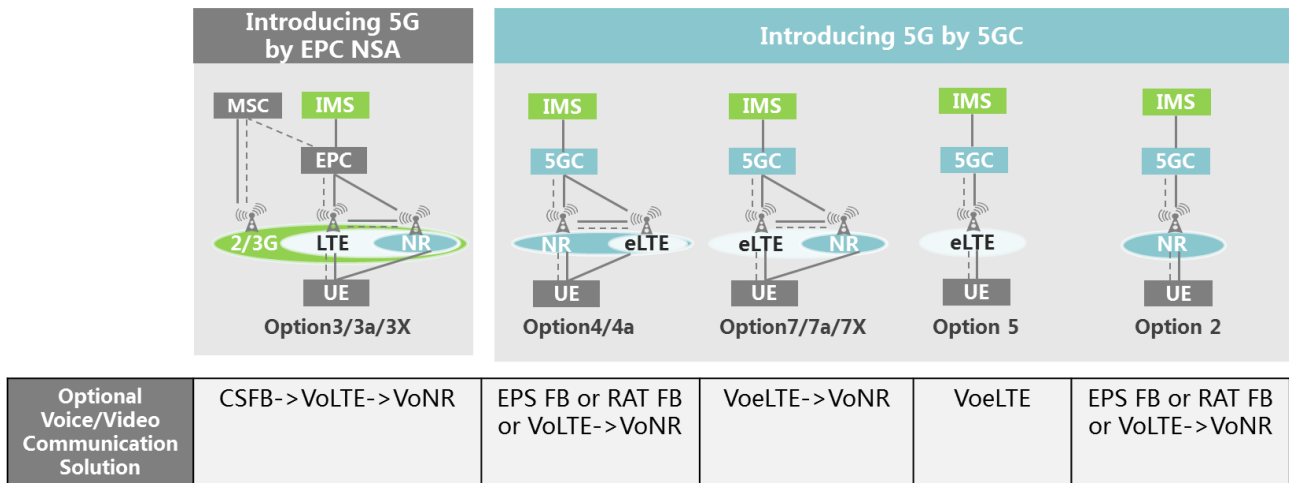
Figure 2-1 5G Voice Solution Options

As shown in the preceding figure, in addition to VoNR, the voice/video communication solutions EPS fallback (EPS FB), RAT fallback (RAT FB), and voice/video over eLTE (VoeLTE) (Note 1) need to be implemented by using the 5G core network (5GC). These solutions are not defined in the 4G era. Therefore, VoNR cannot represent all 5G voice/video communication solutions. The industry needs to use Vo5G to summarize all 5G voice/video communication solutions. Vo5G should include VoNR, VoeLTE, EPS FB, and RAT FB.

Note1: eLTE, which is also called ng-eNB, supports the access to the 5GC after a 4G base station is upgraded. For details about the definition of the eLTE architecture, see 3GPP TS 38.300.

2.2 Vo5G Standard Development

At the beginning of 5G standardization, voice/video communication services have been fully considered. By June 2018, 3GPP has completed the definition of basic Vo5G functions in Release 15, meeting the requirements of commercial deployment of 5G networks.

2017	2018	2019
Rel-15 : Defines E2E 5G voice/video communication service		**Rel-16 : Enhances the 5G voice/video communication service**

- **Related to access**
  - The voice/video communication service can be carried on the NR/eLTE
  - EPS/RAT Fallback
- **Related to IMS**
  - Supporting 5G access network information
  - Supporting 5G location information

- **Related to access**
  - Coverage optimization for VoeLTE/NR
  - 5G-to-3G SRVCC
- **Related to IMS**
  - IMS support 5G network slicing
  - IMS support Service Based Interface

Figure 2-2 Vo5G Standard Development

There are many options for 5G networking. The voice/video communication solution has been standardized regardless of whether 5G is introduced by EPC NSA or is introduced by 5GC. After the 5GC is introduced, the 5GC does not provide the CSFB solution to simplify the network and accelerate the exit of the CS voice.

2.3 Voice and Video Codec Standard Development

According to GSMA and 3GPP, EVS (Note 2) and H.265 are mandatory codec for voice and video communication services in Vo5G. Compared with VoLTE AMR and H.264, EVS and H.265 require fewer bandwidths to provide better user experience.

In the future, 3GPP will complete the standardization of Immersive Voice and Audio Services (IVAS) in Release 16. IVAS provides better user experience and higher error robustness under various transmission conditions from clean channels to channels with packet loss and delay jitter. IVAS provides support for a range of service capabilities, e.g., from mono to stereo to fully immersive audio encoding/decoding/rendering.

At the same time, ITU and ISO have set up a joint research team, which is studying the next-generation video codec standard H.266. A new generation of video standards will be released in 2020. Currently, with the technologies accumulated in the industry, H.266 has improved the performance by over 40% compared with H.265. H.266 will be the most advanced video compression technology solution in the industry.

With the continuous evolution of the voice and video codec, IVAS and H.266 are expected to take the lead in Vo5G, continuously improving user experience.

Note 2: Enhanced Voice Services (EVS) is standardized in 3GPP Release 12 and is the voice codec providing high error robustness and good voice quality at present.

2.4 Introduction to the Vo5G Voice/Video Communication Solution

2.4.1 VoNR

VoNR indicates that the voice/video communication service is carried on the gNB. There are two options based on different 5G networks:

1. The 5GC and gNB are used to carry VoNR, as shown in the following figure.
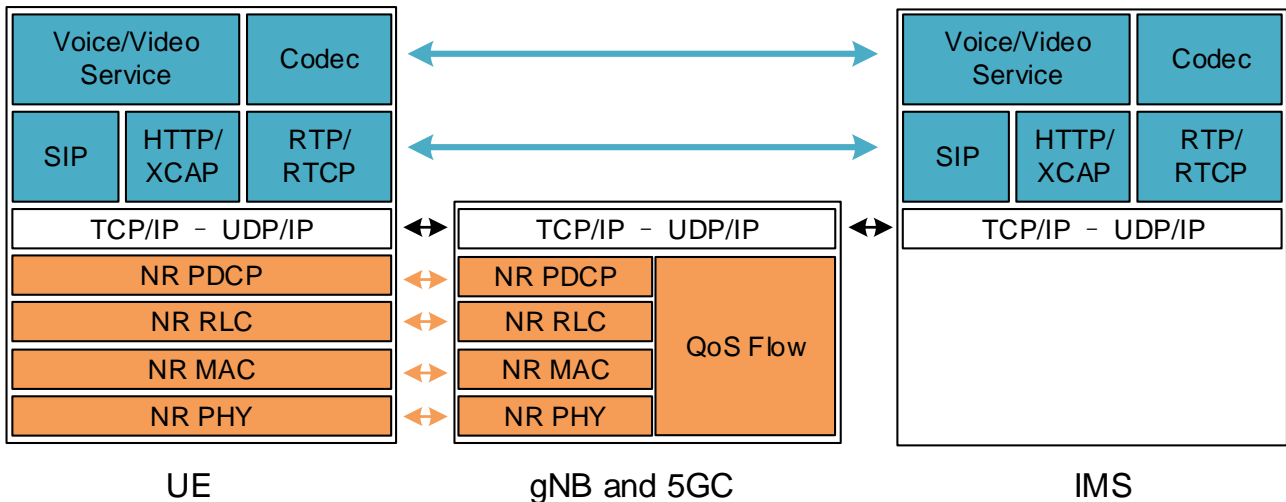
Figure 2-3 VoNR Protocol Stack via 5GC and gNB

2. The EPC and gNB are used to carry VoNR, as shown in the following figure.
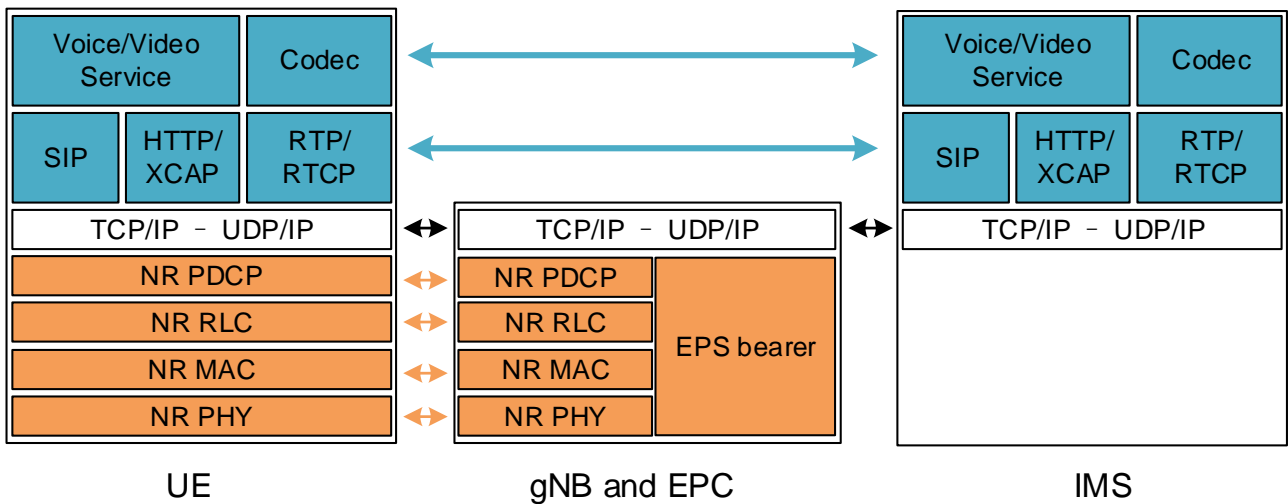
Figure 2-4 VoNR Protocol Stack via EPC and gNB

In VoNR, UEs camp on the NR network, and voice/video communication and data services are carried on the NR network. When a UE moves to the area where the NR signal coverage is poor, a coverage-based handover needs to be initiated to implement the interworking with the 4G network. Then, the UE handovers to the LTE network, and the VoLTE service is provided.

2.4.2 EPS FB

The description of EPS FB is as follows:

The 5G NR network does not provide voice/video communication services at the initial stage. When the gNB establishes an IMS voice/video communication channel on the NR network, a handover is triggered. In this case, the gNB sends a redirection or inter-RAT handover request to the 5GC to fall back to the LTE network and use the VoLTE service, as shown in the following figure.

Establishing the QoS flow for IMS voice

Redirection/Handover procedure to EPS

Figure 2-5 EPS Fallback Protocol Stack

User experience of EPS FB is similar to that of 4G CSFB. If the UE camping on the 5G NR network makes a call, the voice/video communication and data services fall back to the 4G network. The connection duration is 1 to 2 seconds longer than that of the VoNR. However, there are differences between user experience of EPS FB and that of 4G CSFB. For example, certain services, such as USSD, do not trigger EPS FB.

The deployment of EPS FB requires overlapping coverage of LTE and NR networks. The advantage of EPS FB is that the UE or gNB only needs to support the IMS signaling channel (SIP over NR, low real-time requirements), and does not need to support the IMS voice/video communication channel (RTP or

RTCP over NR, high real-time requirements). The RTP or RTCP over NR requires continuous optimization on the NR network to achieve good voice quality and low power consumption of the UE. With this technology, carriers can focus on developing data services at the initial stage of 5G NR, and then evolve to VoNR after the NR network coverage and optimization are complete.

2.4.3 VoeLTE

VoeLTE refers that the voice/video communication service is carried on the 5GC and ng-eNB, as shown in the following figure.
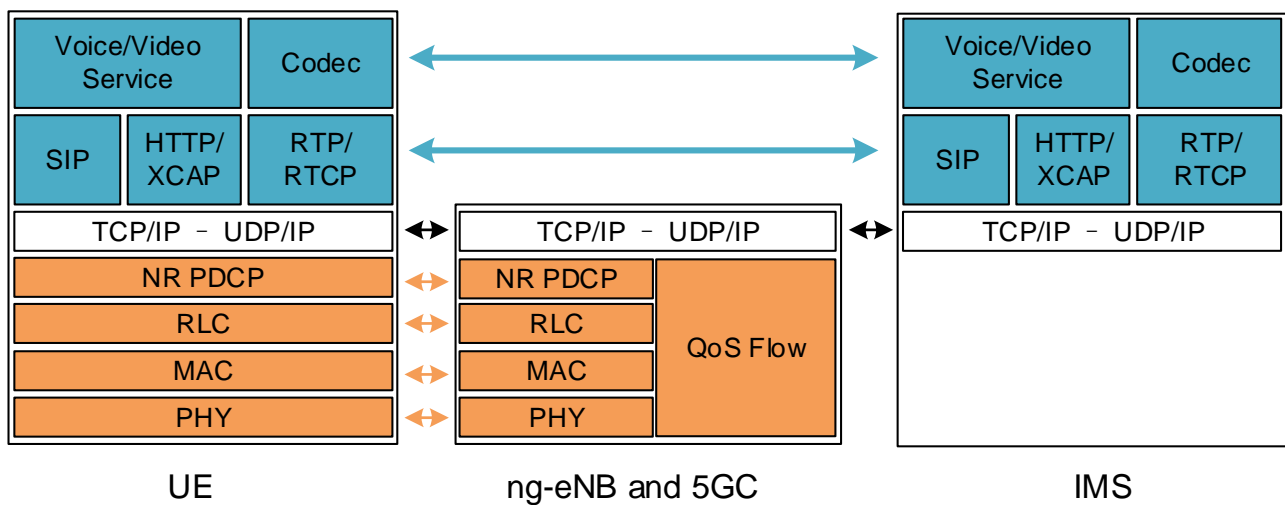
Figure 2-6 VoeLTE Protocol Stack

In VoeLTE, UEs camp on the eLTE network, and voice/video communication and data services are carried on the eLTE network. When a UE moves to the area where the eLTE signal coverage is poor, a coverage-based handover needs to be initiated to implement the interworking with the 4G or NR network. Then, the UE handovers to the LTE or NR network, and the VoLTE or VoNR service is provided.

2.4.4 RAT FB

The description of RAT FB is as follows:

Similar to EPS FB, the 5G NR does not provide voice/video communication services at the initial stage. When the gNB establishes an IMS voice/video communication channel on the 5G network, a handover is triggered. In this case, the gNB sends a redirection or inter-RAT handover request to the 5GC to fall back to the eLTE network and use the VoeLTE service, as shown in the following figure.
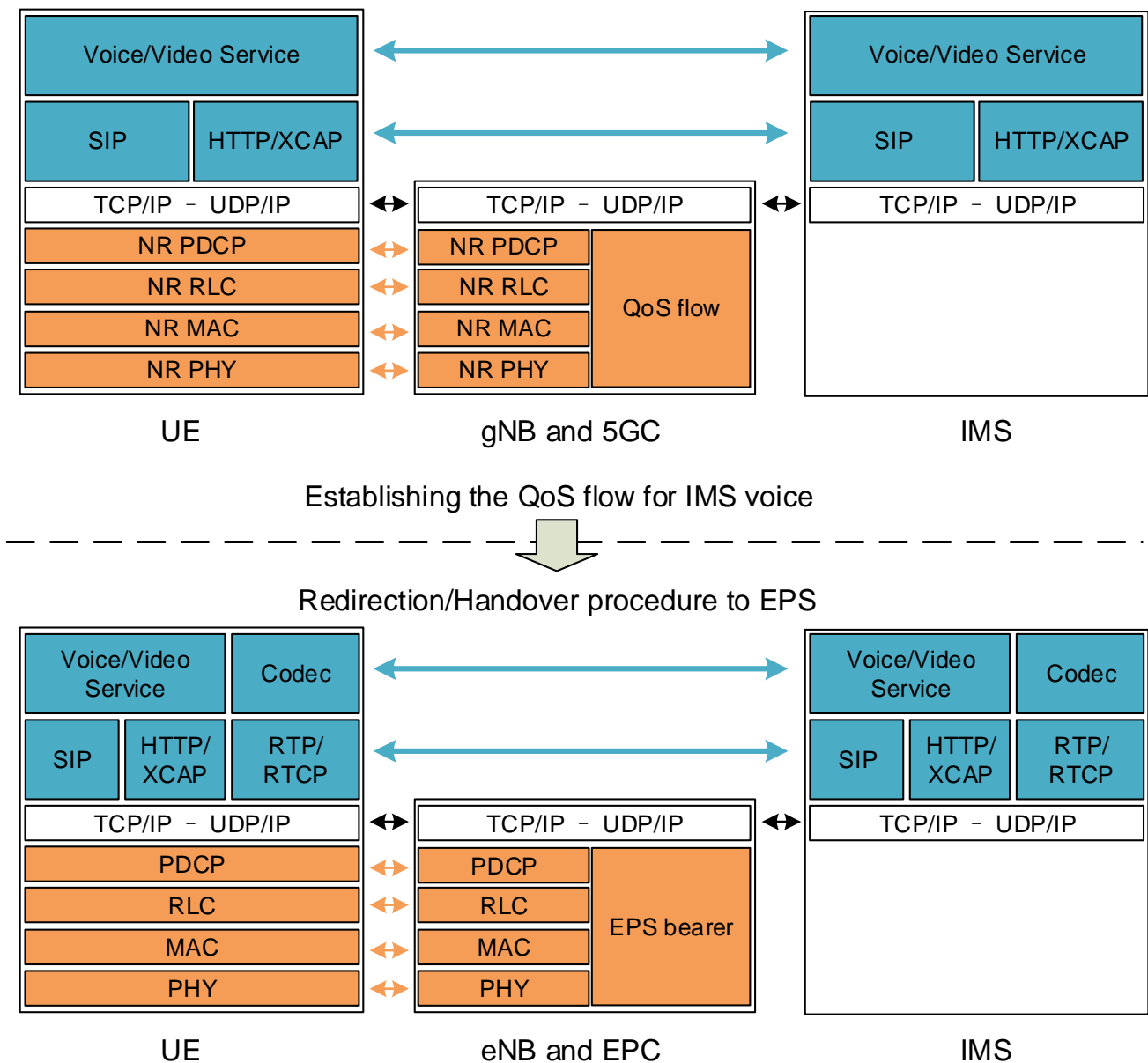
Figure 2-7 RAT Fallback Protocol Stack

User experience and introduction causes of RAT FB are the same as those of EPS FB. The deployment of RAT FB requires overlapping coverage of eLTE and NR networks. It is used for NR and LTE networks without overlapping coverage, and the gNB does not deploy an IMS voice/video communication channel (RTP or RTCP over NR).

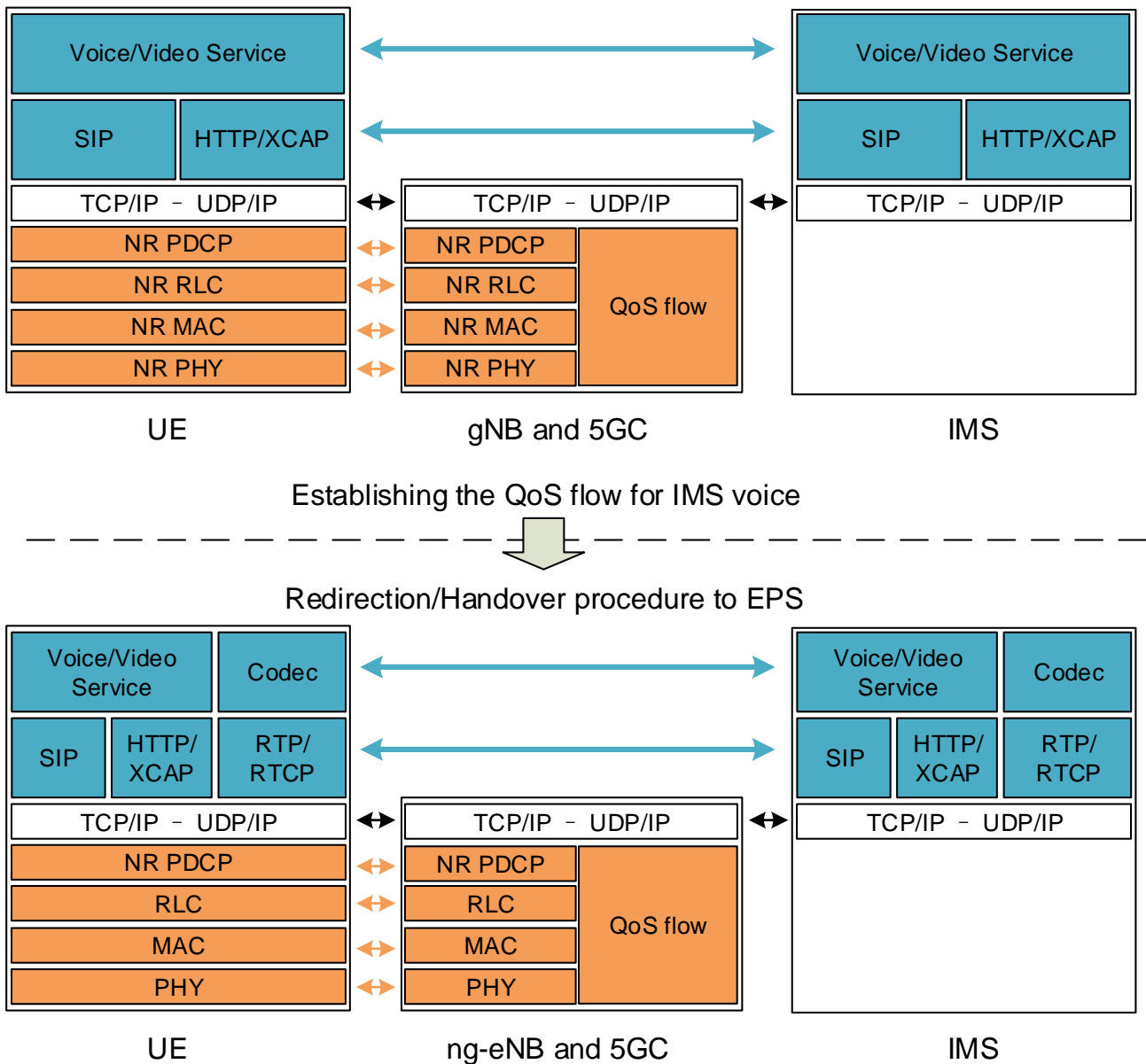# 2.5 Introduction to the Vo5G SMS and USSD Solutions

In Vo5G, the short message service (SMS) and USSD solutions are implemented through the 5GC and IMS regardless of VoNR, EPS FB, VoeLTE, or RAT FB.

The SMS solution is implemented through SMS over IMS. For details, see 3GPP TS 23.204.

The modification of supplementary services is implemented over the XCAP/Ut interface. For details, see 3GPP TS 24.623.

The USSD solution is implemented through USSD over IMS. For details, see 3GPP TS 23.390.

2.6 Vo5G Solution on Different 5G Networks

2.6.1 Introducing 5G by EPC NSA

For 5G option 3/3a/3X, the NR is provided by the gNB, and the gNB serves as the secondary node of the master node of eNB to access the EPC network, as shown in the following figure.
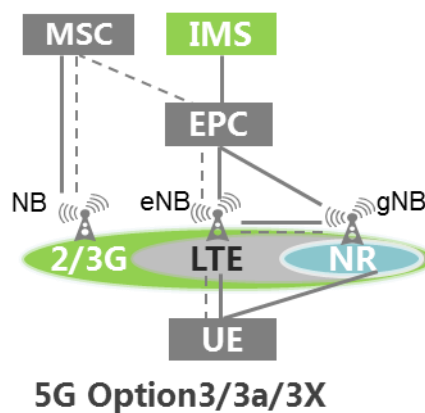
Figure 2-8 5G option 3/3a/3X Networking

1. Voice/Video Communication

In the networking, the voice/video communication services can continue using technologies, such as the CSFB and VoLTE, or using the VoNR technology under the NR coverage. Generally, carriers can select evolution from CSFB to VoLTE, and then choose to evolve to VoNR.

In the networking, there are two options for using the VoLTE technology:

1) VoLTE over E-UTRA PDCP defined on the 4G network
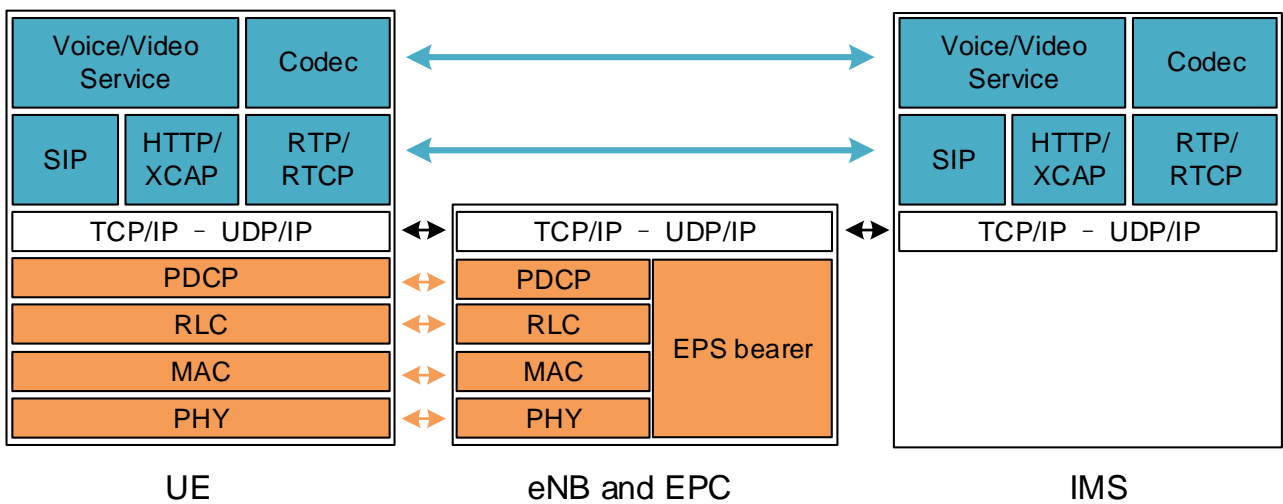
Figure 2-9 VoLTE over E-UTRA PDCP Protocol Stack

2) VoLTE over NR PDCP
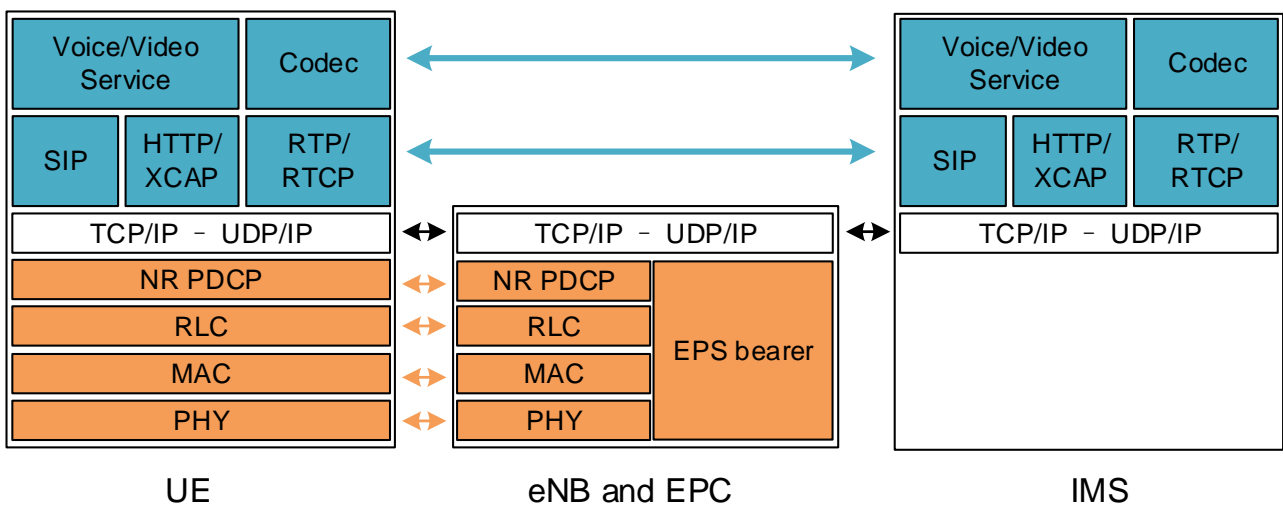
Figure 2-10 VoLTE over NR PDCP Protocol Stack

3GPP TS 37.340 is for option 3 networking. The eNodeB can support NR PDCP or E-UTRAN PDCP. If only NR PDCP is supported, the variant VoLTE over NR PDCP is introduced. Although no new function is provided for VoLTE, the introduction of new protocol stacks will increase the workload of network optimization and UE power consumption optimization.

2. SMS and USSD

The SMS solution can use the SMS over SGs or SMS over IMS technology. The USSD solution can use the CSFB or USSD over IMS technology.

2.6.2 Introducing 5G by 5GC

1. SMS and USSD

The SMS solution can only use the SMS over IMS technology. The USSD solution can only use the USSD over IMS technology.

2. Voice/Video Communication

1) 5G option 7/7a/7X

The networking is evolved from option 3/3a/3X. With the deployment of 5GC, option 3/3a/3X originally connected to the EPC can be cut over to the 5GC.
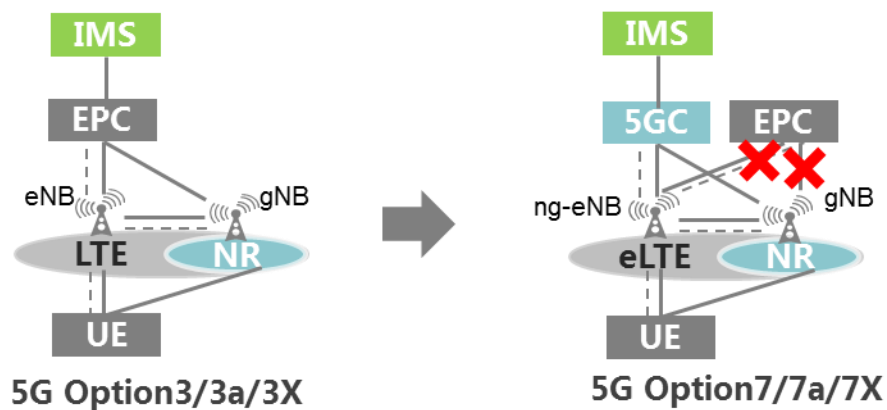
Figure 2-11 5G Option7/7a/7X Networking

In the networking, the CSFB technology cannot be used because there is no interface between the 5GC and MSC. The voice/video communication service needs to use the VoeLTE technology, or use the VoNR technology under the NR coverage. Carriers can choose to evolve to VoNR.

2) 5G Option5
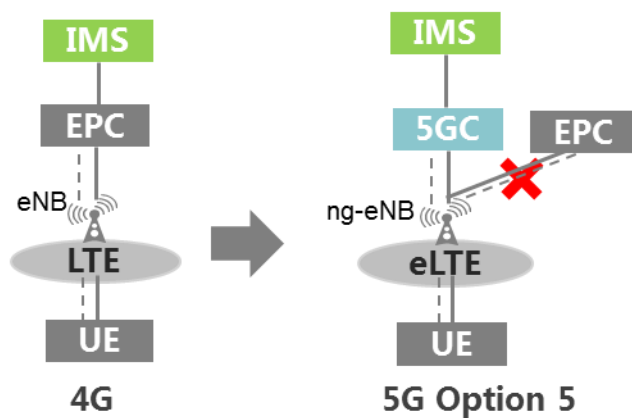
Figure 2-12 5G Option5 Networking

The networking is evolved from the LTE networking. With the deployment of 5GC, the eNodeB originally connected to the EPC is upgraded to ng-eNB and can be cut over to the 5GC.

In the networking, the CSFB technology cannot be used because there is no interface between the 5GC and MSC. The voice/video communication service requires the VoeLTE technology.

3) 5G Option2

The networking is the target 5G networking. VoNR can be selected for the voice/video communication services, as shown in the following figure.
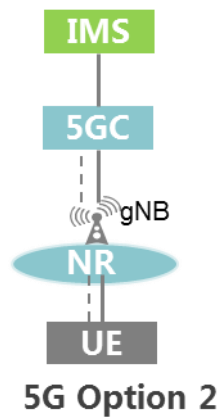
Figure 2-13 5G Option2 Networking

In addition, at the initial stage of 5G deployment, NR and 4G network coverage is overlapped. Therefore, EPS FB can be preferentially selected for voice/video communication services. Then, VoNR is used, as shown in the following figure.
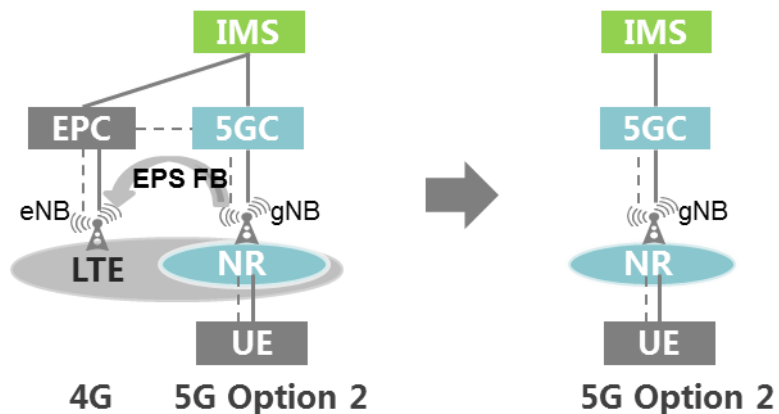
Figure 2-14 Evolution from EPS Fallback to VoNR

Alternatively, at the initial stage of 5G deployment, NR and 4G network coverage is overlapped. Carriers can select the dual registration solution (Note 3). The UE (Note 4) can access the EPS and 5G system (5GS) at the same time. The voice/video communication service is carried using VoLTE in the EPS, and data services can be carried in the NR/5GS or LTE/EPC based on coverage. Then, VoNR is used, as shown in the following figure.
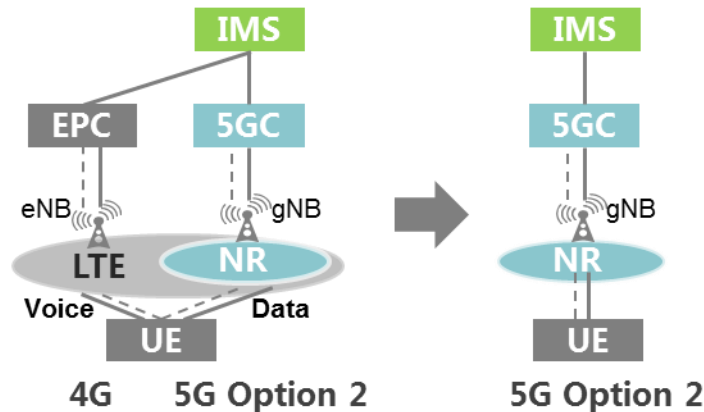
Figure 2-15 Evolution from VoLTE of dual registration to VoNR

Note 3: Dual registration is defined in 3GPP TS 23.501 and 3GPP TS 23.502.

Note 4: The UE can use dual Rx/Tx or 1Tx+2Rx to meet requirements of simultaneous access to the EPS and 5GS. In this case, the power consumption of the UE is high.

Alternatively, at the initial stage of 5G deployment, NR and eLTE network coverage is overlapped. Therefore, RAT FB can be preferentially selected for voice/video communication services. Then, VoNR is used, as shown in the following figure.
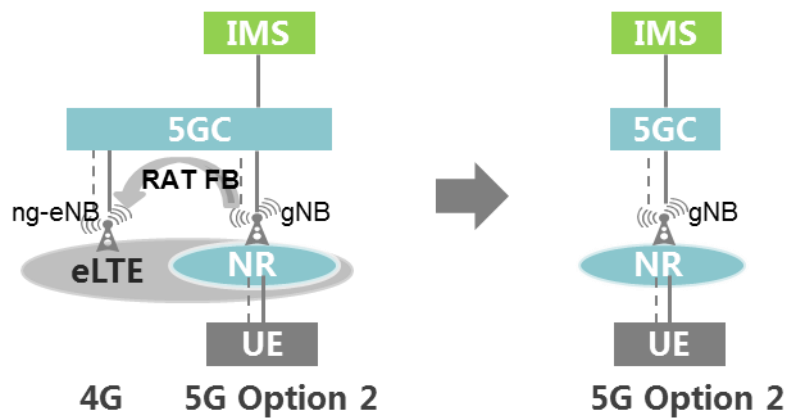
Figure 2-16 Evolution from RAT Fallback to VoNR

4) 5G Option4/4a

The networking is enhanced on the basis of 5G option 2, and the secondary node of the eLTE is added.
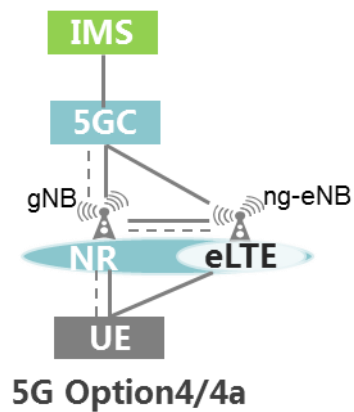
Figure 2-17 5G Option4/4a Networking

The NR coverage scope of the master node is larger than that of the eLTE secondary node. Therefore, the voice/video communication service is optional on the secondary node. The voice/video communication solution options of the networking are the same as those of option 2.

3 Vo5G Is an Important Technology for Accelerating 5G Development

5G development requires more spectrum resources, especially low-frequency resources with good penetrating capabilities. High-quality low-frequency resources are occupied by 2G or 3G networks for voice/video communication and cannot be released. With the introduction of 5G, carriers will face the challenge of coexistence of 2G, 3G, 4G, and 5G networks. Too many RATs and networks result in high CAPEX and OPEX. Vo5G can accelerate the migration of voice/video communication from 2G or 3G networks to 4G or 5G networks, reducing the number of networks and costs as well as refarming low-frequency resources for 5G.

Vo5G provides the same user experience as VoLTE. A voice/video call is connected within a short period, only about 1 to 2 seconds from dialing to hearing the ring back tone. While making the call, subscribers can also enjoy high-speed 4G or 5G Internet access, for example, by accessing a high-speed download service.

In addition, EVS and H.265 codec is mandated for Vo5G, which provides better user experience. The voice bandwidth (ultra-broadband and full bandwidth) is expanded, and the high error robustness of voice and video communication services is improved.

Vo5G will be fundamental to accelerate 5G development because both carriers and subscribers are willing to use Vo5G.

4 Road to Vo5G: IMS Readiness Is the Prerequisite

3GPP has specified that 5G must provide voice/video communication services based on the IMS, that is, the IMS must be deployed for VoNR, VoeLTE, EPS FB, and RAT FB in 3GPP Release 15 or 5G-to-3G SRVCC in 3GPP Release 16.

After years of VoLTE construction, IMS deployment is no longer complex. There are standard solutions to difficulties, such as inheritance of services on the 2G or 3G networks and CS and IMS service consistency. At the same time, the IMS is the product that first adapts to cloud-based transformation of telecommunication networks and commercially deploys NFV.

IMS deployment has entered the fast lane. According to statistics of GSMA (Note 5), 138 carriers around the world had launched IMS-based VoLTE networks by May 2018.

Note 5: The data is from
https://www.gsma.com/futurenetworks/resources/all-ip-statistics/

5 Road to Vo5G: Accelerating VoLTE Commercialization Is the Basis

5.1 Voice Solution Selected at the Initial Stage of 5G Commercialization

At the 2018 IMS World Forum (Note 6), a carrier-oriented survey shows that nearly half of carriers will first choose EPC NSA to introduce 5G.

Note 6: IMS World Forum (https://tmt.knect365.com/ims-world-forum/) is the only professional forum that focuses on the IMS technology, innovation, evolution, and ecosystem and has great influence in the industry.

Which 5G option will be deployed at initial phase? (Check one) 037

using 5GC and NR gNB access

22 %

using EPC and an LTE eNB acting as master and NR gNB acting as secondary

49 %

using 5GC and eLTE ng-eNB access

16 %

using 5GC and an NR gNB acting as master and eLTE ng-eNB acting as secondary

5 %

using 5GC and an eLTE ng-eNB acting as master and an NR gNB acting as secondary

8 %

Figure 5-1 Selection of 5G Deployment Options

75% carriers select VoLTE as the solution for Vo5G at the initial stage. No carrier selects CSFB as the solution for Vo5G at the initial stage.

Which Vo5G option will be used at initial phase? (Check one)
(1/2)

0 3 2

CSFB
0 %

VoLTE
75 %

VoNR
6 %

EPS/RAT Fallback
9 %

VoeLTE
9 %

Figure 5-2 Selection of 5G Voice Solutions

5.2 Evolution to VoNR

VoNR is the target voice/video communication solution for 5G networks. There are multiple methods to transform the voice/video communication solution selected at the initial 5G stage to VoNR. By June 2018, Huawei Marketing Intelligence (MI) has investigated global carriers who will deploy 5G networks, and the investigation results show that there are three VoNR evolution paths.
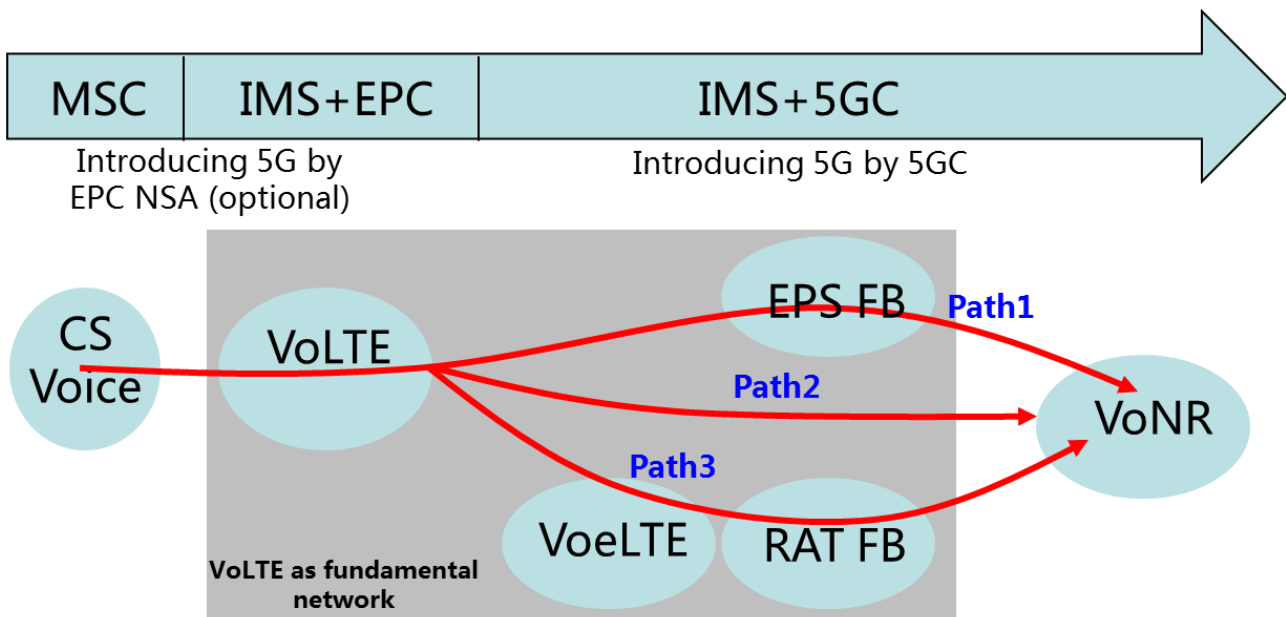
Figure 5-3 Evolution to VoNR

5.2.2 Path1: VoLTE->EPS FB->VoNR

At the initial stage of 5G, voice/video communication and data networks are separated. Voice/video communication services are provided by the EPC and LTE, and VoLTE is used as the voice/video communication solution. With the introduction of the 5GC, voice/video communication services are still provided by the EPC and LTE, and EPS FB is used as the voice/video communication solution. After the 5G network is further optimized, VoNR is gradually provided using either of the following 5G evolution methods:

- 4G->5G Option3/3a/3X->5G Option2

- 4G->5G Option2

5.2.3 Path2: VoLTE-> VoNR

Voice/video communication and data services are provided on the 5G network using the following method:

- 4G->5G Option2

5.2.4 Path3: VoLTE-> VoeLTE->RAT FB->VoNR

At the initial stage of 5G, voice/video communication and data networks are separated, and the NR+LTE networking is adopted. Voice/video communication services are provided by the EPC and LTE, and VoLTE is used as the voice/video communication solution. With the introduction of the 5GC, the NR+LTE networking is still adopted, voice/video communication services

are provided by the 5GC and LTE, and VoeLTE is used as the voice/video communication solution. The NR SA networking is introduced gradually, voice/video communication services are still provided by the 5GC and LTE, and RAT FB is used as the voice/video communication solution. After the 5G network is further optimized, VoNR is gradually provided using the following 5G evolution method:

- 4G->5G Option3/3a/3X->5G Option7/7a/7X->5G Option2

5.3 Accelerating VoLTE as the Fundamental Network of Vo5G

The traditional CS voice service is gradually phasing out from the 2G or 3G CS voice service to 4G VoLTE and from 2G or 3G CS-domain voice service continuity supported by VoLTE to only IMS-based voice services supported by Vo5G. For carriers, as 5G approaches, VoLTE deployment becomes increasingly urgent.

For 5G, the networking is complex. The key to success requires the assurance of service continuity and economic and effective network deployment. OPEX and CAPEX can be effectively reduced by providing the voice/video communication services only on the 4G or 5G networks with the 2G or 3G voice networks shut down based on site conditions. VoLTE will become the basic voice/video communication network in the 5G era and work with Vo5G to ensure the continuity of voice/video communication services.

6 After Vo5G: Industry-oriented Real-Time Voice and Video Communication Evolves Continuously

6.1 5G Will Bring New Changes to Carriers' Real-Time Voice and Video Communication

Currently, there are 7 billion people-to-people voice and video connections around the world. As 5G is coming, voice and video connections will extend to 20 billion people-to-people and people-to-machine connections. 5% to 10% 5G application scenarios, such as UHD videos, AR or VR communication, and IoT, need to be built based on real-time communication capabilities, indicating that voice/video communication services will be transformed from consumer voice/video communication services to enhanced real-time communication network capabilities and will run on the dedicated network and Internet. Terminals also change from mobile phones to TV, watches, cars, and even robots. The changes are good opportunities for voice/video communication services and will enhance user experience and create business value for carriers.

6.2 3GPP Release 16 Has Initiated a Research on the Next-Generation Real-Time Communications Networks

The FS_NG_RTC (Note 7) project has been approved in 3GPP Release 16 in June 2018. The project invites carriers and suppliers to discuss and define the next-generation real-time communications networks, such as how to provide enhanced media planes to support the AR or VR communication and how to define IMS network slices to enable vertical industries.

In addition, the new requirements and applications of real-time voice and video in various industries are key to driving network architecture evolution. More and more vertical industry partners and the entire ecosystem are recommended to participate in the project and jointly plan future-oriented real-time communications networks.

Note 7: For details about the project, visit https://portal.3gpp.org/desktopmodules/WorkItem/WorkItemDetails.aspx?workitemId=800029.

7 Conclusion

Vo5G has been standardized with the standard process of 3GPP 5G. The Vo5G solution is provided based on the IMS.

Vo5G can accelerate the migration of voice/video communication from 2G or 3G networks to 4G or 5G networks, reducing the number of networks and costs as well as refarming low-frequency resources for 5G. Deploying the IMS and accelerating the commercial use of VoLTE are the only way to move towards Vo5G.

5G will greatly change our society and lives. The entire industry needs to plan future-oriented real-time communications networks in advance to continuously evolve to the next-generation communications networks.

8 Glossary

Table 8-1 Abbreviations List

Abbreviations	Description
3GPP	3rd Generation Partnership Project
5GC	5G Core Network
CAPEX	Capital Expenditures
CS	Circuit Switched Domain
CSFB	Circuit Switched Fallback
EPC	Evolved Packet Core
EPS FB	Evolved Packet System Fallback
EVS	Enhanced Voice Services
GSMA	GSM Association
HTTP	HyperText Transfer Protocol
IMS	IP Multimedia Subsystem
IP	Internet Protocol
ISO	International Organization for Standardization
ITU	International Telecommunication Union
IVAS	Immersive Voice and Audio Services
LTE	Long Term Evolution
MAC	Medium Access Control Protocol
MI	Marketing Intellgence
MSC	Mobile Switching Center
NR	New Radio
NSA	Non-Standalone
OPEX	Operating Expenses
PDCP	Packet Data Convergence Protocol
PHY	Physical Layer
QoS	Quality of Service
RAT	Radio Access Technology
RAT FB	Radio Access Technology Fallback
RLC	Radio Link Control Protocol

RTCP	RTP Control Protocol
RTP	Real-time Transport Protocol
SA	Standalone
SIP	Session Initiation Protocol
SMS	Short Message Service
SRVCC	Single Radio Voice Call Continuity
TCP	Transmission Control Protocol
UDP	User Datagram Protocol
UE	User Equipment
USSD	Unstructured Supplementary Service Data
Vo5G	Voice over 5G
VoLTE	Voice over LTE
VoNR	Voice over NR
VoeLTE	Voice over eLTE
XCAP	XML Configuration Access Protocol
eLTE	Evolved LTE
eNB	Evolved NodeB
gNB	Next Generation NodeB
ng-eNB	Next Generation Evolved NodeB
VR	Virtual Reality
AR	Augmented Reality
IoT	Internet of Things