# Voice over 5G: The options for deployment

## Technical options and migration paths for service providers

White paper

Although 5G networks will be driven by gigabit mobile broadband, ultra-reliable low latency applications and machine-to-machine communications, voice will remain a key part of the business case for communications service providers.

This second white paper on Voice over 5G (Vo5G) from Nokia explains why IMS-based VoLTE forms the basis of 5G voice services and explores the 3GPP deployment strategies, the differences between EPS Fallback and CS Fallback and how the IMS will become part of the cloud-native 5G Core.

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# Executive Summary


Despite the focus on the headline abilities of 5G such as ultra-low latency and support for network slicing, voice will remain a vital service that Communication Service Providers (CSPs) will continue offering with the new networks.

There are several options for deploying 5G and the way voice service is provided will depend on which option is chosen. This white paper focuses on 3GPP Option 3x and Option 2, as they are the two key deployment options for the introduction of 5G.

Option 3x is used in early 5G deployments. Voice services are provided in this approach by the existing 4G VoLTE network, or possibly a 3G network. The 5G connection is used for data only.

Option 2 requires deploying the 5G Core, including a number of elements which are not required in Option 3x. Voice services are provided in one of two ways. The first is EPS Fallback, where a mobile phone will be forced to fall back from 5G to LTE during voice call set-up. Voice and data traffic is carried over LTE for the duration of the call. The second uses Voice over New Radio (VoNR), where voice is natively handled over the 5G radio, allowing simultaneous voice and high-speed 5G data. Although VoNR is the long-term endpoint, mobile phones and networks are expected to support only EPS Fallback on initial deployment of Option 2.

In every deployment option, the 3GPP IP Multimedia Subsystem (IMS) is used as the technology basis to provide voice and video communication services over 5G radio. Therefore, the planning for 5G introduction always includes a discussion around IMS and preparation of the existing 2G, 3G, or 4G network.

# The deployment options for 5G

Although it is not a key driver for 5G, the continuity of voice services is essential. It is therefore vital to understand how voice services can be provided in the various 5G deployment options.

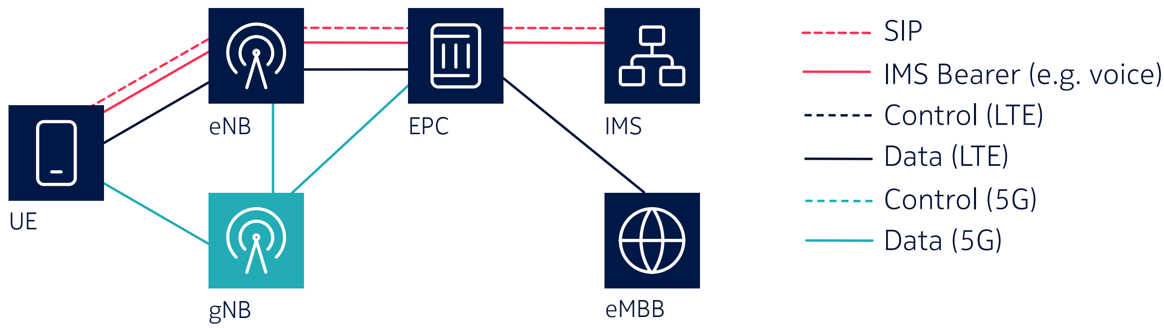
The 3rd Generation Partnership Project (3GPP) defines a number of 5G deployment options – the most important being Options 2, 3 (and 3x), 4, 5 and 7. We focus on Option 3x and Option 2, as they are the two key deployment options for voice. The other options can be viewed as variants of Options 3x and 2, which all include a 5G Core deployment but differentiate in their use of Long Term Evolution (LTE), enhanced LTE (eLTE) or New Radio (NR). Further, the variations that differentiate Options 4, 5, and 7 have no additional implications for the IP Multimedia Subsystem (IMS) network that provides the voice services in every option.

Figure 1. Non-Standalone and Standalone deployment options for 5G

## NSA Option 3x

Non-standalone (NSA) Option 3x used in early 5G deployments provides additional bandwidth for mobile broadband data services based on the higher 5G radio frequency ranges, by adding 5G base stations into an existing 4G network.

Figure 2. The architecture of Option 3x




Although LTE continues as the primary control network, the 5G base station acts as an extension to support extreme high-speed mobile data. 5G radio is initially expected to support best effort data packet delivery only, with other quality of service types deployed afterwards.

With Option 3x, the existing 4G IMS/Voice over LTE (VoLTE) network is used to provide voice services with very minor or no changes. This includes the use of Single-Radio Voice Call Continuity (SR-VCC) for the seamless handover of voice calls between LTE/VoLTE and 2G/3G CS voice networks. The drawback is that the user's mobile phone must support dual radio connectivity with resulting impact on battery life.

If a CSP has not yet deployed IMS for voice but does have 4G LTE, voice services can still be provided using the 2G or 3G network with Circuit Switched (CS) Fallback from LTE. However, the customer experience will still suffer the same degradation that occurs today with CS Fallback.

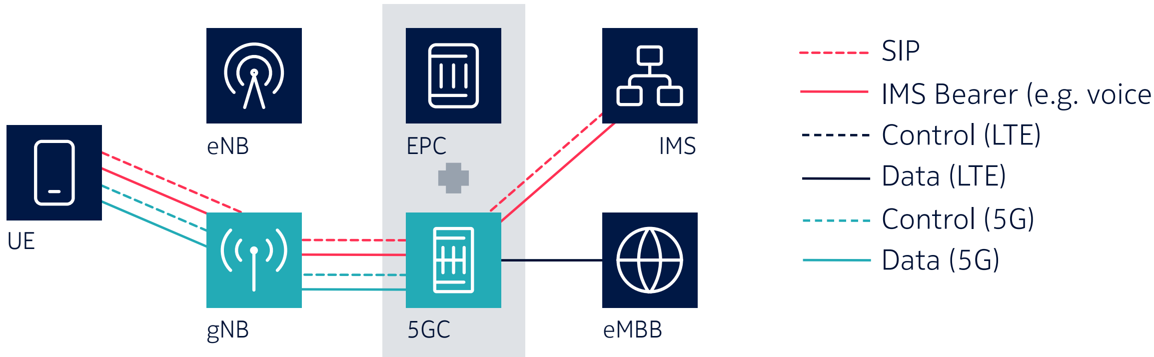
## SA Option 2

For standalone (SA) Option 2, the 5G Core is introduced into the network, including a number of elements which are not required in Option 3x.

Broadly speaking, Option 2 has two voice solution alternatives:

- Voice over New Radio (VoNR). This uses IMS-based voice functionality, allowing a simultaneous voice and high-speed 5G data experience. The approach is the same as is used today to provide VoLTE service with IMS. This is the target solution.
- EPS Fallback. A mobile phone will be forced to fall back from 5G to 4G LTE during voice call set-up. After EPS Fallback, IMS voice and data traffic is carried by the existing LTE network while the call is active. This is the voice solution for initial deployments, and the only voice solution the first 5G SA handsets will support.

Figure 3. The architecture of Option 2 as used for VoNR




With VoNR, the device can attach and receive full voice and data services natively on the 5G radio. Network coverage is no longer restricted to LTE service areas, as is the case in Option 3x, however, LTE coverage will continue to be important due to the practical issue that 5G radio has shorter range due to its higher frequencies.

With EPS fallback, the deployment continues to require dual radio handsets, which negatively impacts the user experience just as the approach does for Option 3x, since the 5G radio is turned off and the 4G radio is used for both voice and data during voice calls.

# How IMS works with the 5G Core

## IMS Support for SA Option 2 and Voice over NR

When 3GPP defined 5G in 3GPP Release 15 (Rel-15), the impact on IMS was minimized to assist with 5G deployment. From an IMS point of view, Rel-15 5G Core looks similar to the 4G Evolved Packet Core (EPC):

- The Home Subscriber Server (HSS) remains responsible for handling the IMS user profile.
- Proxy-Call Session Control Function (P-CSCF) discovery performed by the device during IMS signaling flow establishment is supported by 5G Session Management Function (SMF).
- The P-CSCF in IMS may continue to use the Rx interface to the 5G Policy Control Function (PCF). Equivalent Quality of Service (QoS) classes have been defined in 5G for IMS signaling and voice traffic.
- Several new 5G capabilities have not been applied to IMS – the 4G concepts continue to be used in 5G, e.g. a single bearer anchor and the preservation of IP address.
- Existing 3GPP procedures linking the IMS with the packet core via the HSS and Unified Data Management (UDM) have been extended to support 5G access, e.g. the Terminating Access Domain Selection (T-ADS).

The IMS Private Identifier (IMPI) and the IMS Public Identifier (IMPU) remain unchanged for Vo5G support and the new 5G subscriber identifiers – Subscription Permanent Identifier (SUPI) and Generic Public Subscription Identifier (GPSI) – are not used in the IMS.

The net result is that the existing IMS solution used to provide VoLTE services in 4G can be re-used to provide Voice over NR services, provided some small, but essential interface extensions are made, and the service logic in the IMS is adjusted to handle these. See figure 4 for details.

### Figure 4. How IMS interfaces are changed to support 5GC and NR

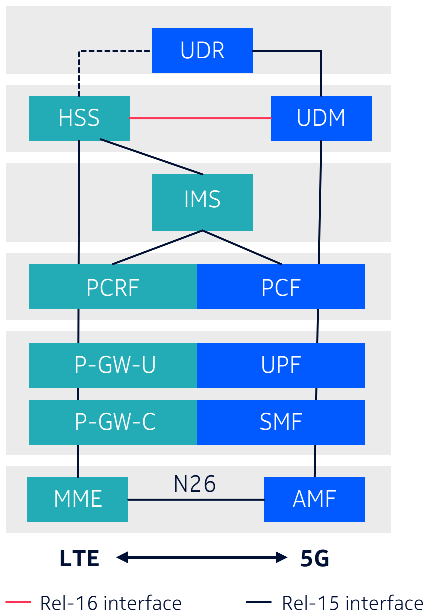
| IMS Interface | Impact for the support of 5G Option 2 in 3GPP Rel-15 |
|---|---|
| Rx | This interface was extended to support IMS policy control for the 5G access. 5G related information carried over the Rx-interface are the 5G Radio Access Technology (RAT) Type, the 5G User Location Information, and the 5G Charging Correlation ID |
| Cx | There is no impact of 5G on the IMS Cx-interface |
| Sh | This interface was extended to provide User Location Information-, User State-, UE Reachability- and Terminating Access Selection (T-ADS) support for the 5G access. 5G related information carried over the Sh-interface are the 5G RAT Type, the 5G User Location Information, the AMF address (and the SMSF address for SMS over NAS). |
| Gm, Mw, ISC, Mg, Mj, Mk, Mx | The existing SIP P-Access Network-Info header was enhanced to support the new 5G RAT type and 5G User Location Information. In addition, the existing SIP P-Charging-Vector header was enhanced to carry the 5G Access Charging ID which is used for Charging Correlation with 5G.<br>All SIP interfaces are affected. |
| Rf, Ro, Bi | These interfaces were extended to support IMS online- and offline charging when the 5G access is used. 5G related information carried over the Rf, Ro, Bi interfaces are the 5G RAT type, the 5G User Location Information and the 5G Access Charging ID. |

IMS call flows and message sequences are the same in 4G and 5G Rel-15, even though individual messages may carry 5G access network information over Session Initiation Protocol (SIP) and Diameter interfaces. Furthermore, while Rel-15 limits the effect of 5G on the IMS to the absolute minimum, the effect on the packet core and the subscriber data management that supports IMS with 5G access is more significant.

## 5G handover to LTE

Option 2 allows 5G deployments in areas without 4G coverage but there will be many areas where only LTE or 3G can be used. Voice calls, which start in 5G, therefore, need to be handed over to 4G or 3G to create a seamless voice service experience for the end user. Let's look at the voice call handover from 5G to 4G.

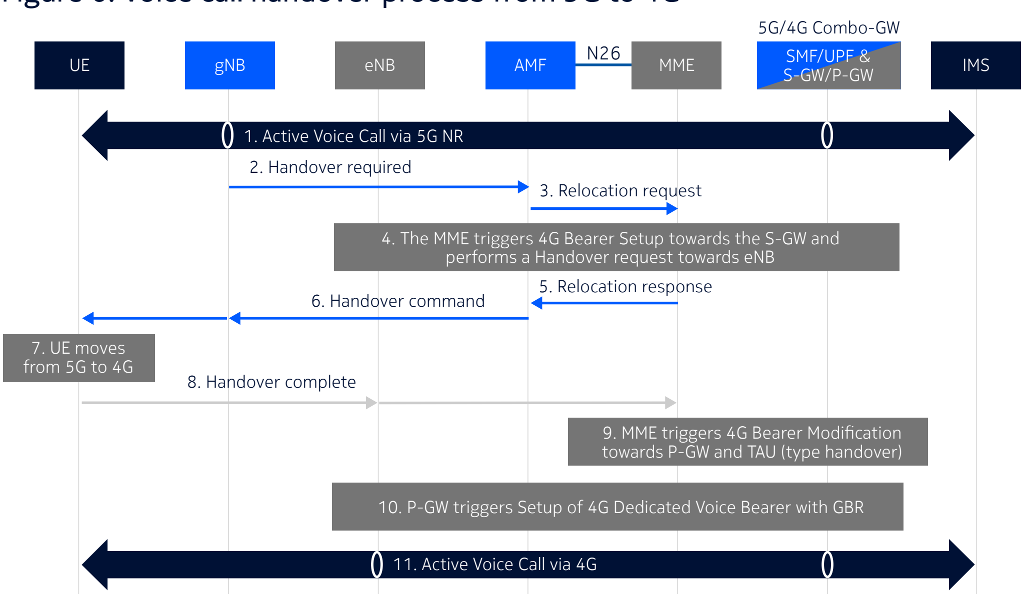
### Figure 5. Network elements used in 5G to LTE voice call handovers




| | |
|---|---|
| AMF | Access and Mobility Function |
| HSS | Home Subscriber Server |
| IMS | IP Multimedia Subsystem |
| MME | Mobility Management Entity |
| P-GW-C | Packet Data Network Gateway (Control) |
| P-GW-U | Packet Data Network Gateway (User) |
| PCF | Policy Control Function |
| PCRF | Policy and Charging Rules Function |
| SMF | Session Mnagement |
| UDM | Unified Data Management |
| UDR | Unified Data Register |
| UPF | User Plane Function |

The voice call handover from 5G to 4G is supported through 'combo-nodes' or 'combo-gateways' (Combo-GW), which provide both 5G core network and EPC functionality and interfaces. From an IMS perspective, the combined SMF/Packet Data Network Gateway (PGW) provides IP address continuity during the handover between 5G and 4G.

### Figure 6. Voice call handover process from 5G to 4G



The UE has an active voice call ongoing over 5G and is reporting the signal strength of the neighboring 4G cells to the gNB. The handover decision is made by the gNB, upon which the gNB indicates this to the AMF in step 2 of the figure. The AMF then informs the MME, which triggers three things: first, the setup of a 4G bearer used later for the IMS Signaling traffic, second the setup of a 4G bearer used later for the voice media. And third, the Handover request to the eNB such that the eNB can allocate the required 4G radio resources.

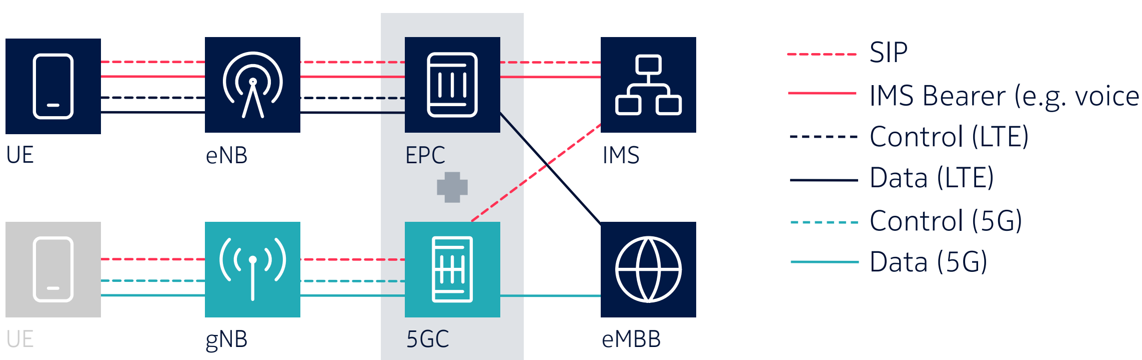
Once this is completed, the AMF sends a Handover Command in step 6, which, when received, triggers the UE to move from 5G to 4G radio. The UE confirms this by sending Handover Complete to the eNB, which immediately notifies the MME. The MME then still needs to complete the bearer setup, by using a bearer modification requests sent towards the P-GW.This completes the voice call handover and all IMS signaling and voice traffic is afterwards carried over 4G radio and core.

Note that in Rel-15, there is no support for voice call continuity between 5G and 3G Circuit Switched (CS). This implies that the Rel-15 mobile network using VoNR in Option 2 must also support IMS/VoLTE to allow calls to continue in 4G when the user moves beyond 5G coverage during an active voice call. However, 3GPP Release 16 (Rel-16) will add support for enhanced Single Radio Voice Call Continuity (eSRVCC) from 5G to 3G CS.

## EPS Fallback

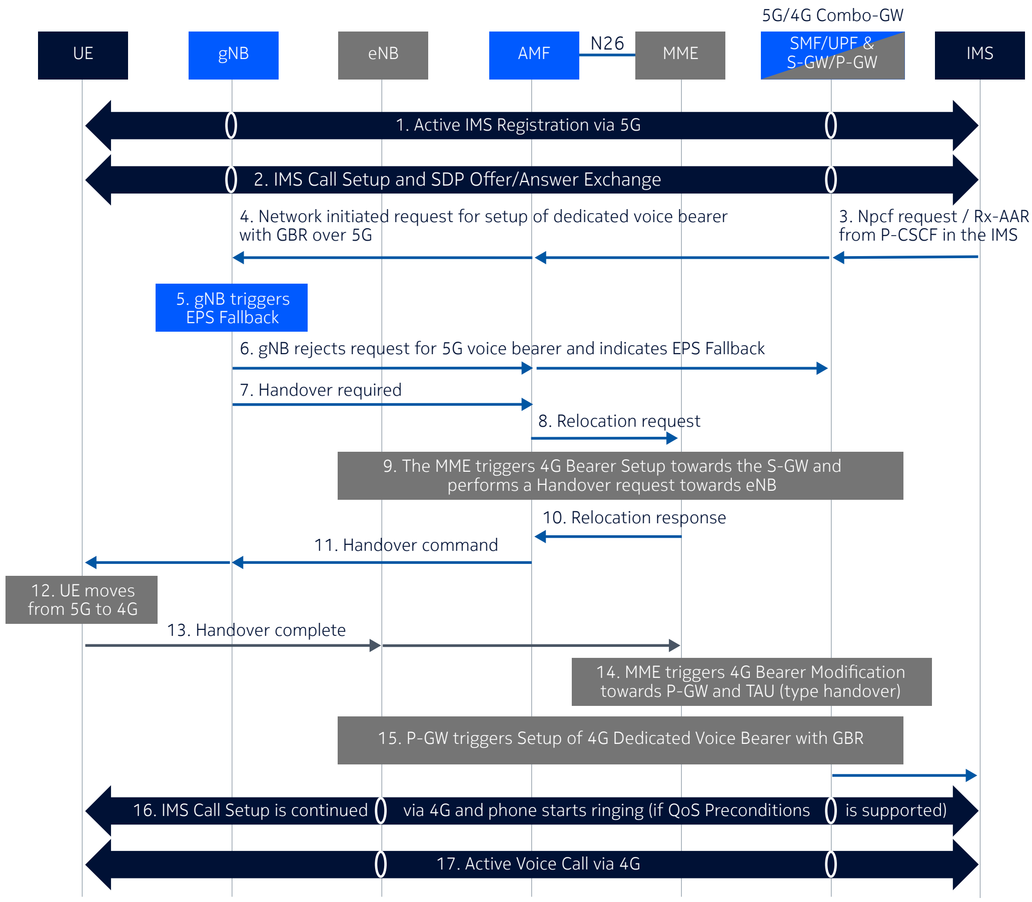
As previously mentioned, the initial voice solutions deployed for 5G Option 2 networks will not include Voice over NR, but will instead employ Evolved Packet System (EPS) Fallback. In this solution, the device is forced to fallback to LTE during the IMS call set-up.

Figure 7. EPS Fallback in Option 2




To support EPS Fallback, 5G New Radio (NR) coverage area must be a subset of the LTE coverage area, with mobility between NR and LTE supported via a combined core network with combo-nodes. The idea behind EPS Fallback is that mobility from 5G to EPS is triggered at the beginning of the call, specifically at the voice bearer establishment request during the IMS call set-up. After triggering, the device switches to use its 4G radio, and is handed over to EPC, where the voice bearer is established over 4G LTE radio. Since the phone has switched to the 4G radio, any data sessions active are also forced from 5G NR to 4G LTE.

Figure 8. Voice call establishment with EPS Fallback




The UE is in the 5G network, has a 5G flow established for IMS signaling traffic and is actively registered in the IMS network. If the end-user initiates a voice call, then this translates to a SIP call setup request sent from the UE towards the IMS. The SIP call flow procedure is, at the beginning, similar to to that for VoNR, but after EPS fall-back it is the same as for VoLTE calls.

In the initial SIP INVITE request and response (usually the SIP 183 Session Progress message), the media description is exchanged. This is often also called the SDP Offer/Answer exchange and is illustrated in step 2 of the figure. After the SDP Offer/Answer exchange, the voice codec usage for the call has been resolved, and with this information, the IMS (the P-CSCF) triggers the Policy Control Function (PCF), to request the establishment of a QoS flow for voice in the 5GC. This is step 3. Note here that the PCF has not been illustrated in the figure for simplicity.

The 5GC then requests the QoS (5QI=1) resources from the gNB. Only at this point, EPS fallback comes into play: the gNB rejects the 5QI=1 flow setup request with an EPS Fallback indication and triggers the handover to LTE. The combined SMF/P-GW suspends the voice bearer setup until the handover to 4G is completed and then establishes a QCI=1 bearer as illustrated in step 14 in the figure above. Afterwards, the IMS call setup continues and is completed in LTE.

The time required for handover adds a small delay but given the excellent voice call set-up times offered by VoLTE, this is acceptable. In fact, the major advantage of EPS fallback is that the handover delay would otherwise result in temporary loss of the voice connection during the call, which is much more perceptible by subscribers than the same delay added during call set-up.

Note that for mobile-to-mobile calls, EPS Fallback may happen for both parties simultaneously if both are in 5G. The initial SIP messages are exchanged over the 5G network, so the IMS and the 5G Core need to support the very same features needed for VoNR.

EPS Fallback may also include a redirect to 4G instead of a handover procedure. In the redirect procedure, the device falls back to 4G and performs an LTE Attach to the same 5G/4G Combo-GW, which suspends the voice bearer set-up until the LTE Attach has been completed. After the voice bearer has been established, SIP call set-up continues in the same manner as the handover procedure. From an IMS point of view, there is no difference between the two.

In summary, EPS Fallback can be viewed as a handover to 4G LTE, which is performed during the IMS call set-up. While EPS Fallback and VoNR are different voice solutions, they are based on the same technical framework and use the same IMS that is widely deployed for VoLTE in 4G. This avoids market fragmentation.

With the introduction of the 5G Core, CS Fallback (CSFB) can no longer be used, because interfaces between the 5G Core and the 3G Core have not been defined for such a procedure. The handover from 5G to 3G for voice calls in Rel-16 is instead a form of enhanced Single Radio Voice Call Continuity (eSRVCC), which is an existing standard for 4G to 3G handover.

# Emergency services

With Option 3x, emergency service calls continue to work in the same way as before, using either the VoLTE based emergency call or CS domain emergency services.

In Option 2 deployments it is possible to use the voice solutions described in the previous sections for emergency services, which may use either VoNR or EPS Fallback. Both options require an extension of the existing emergency solutions. However, there is also a third approach – the Emergency Call Fallback. In this approach, the Fallback to LTE happens before the IMS call set-up, a method recommended for initial deployments.

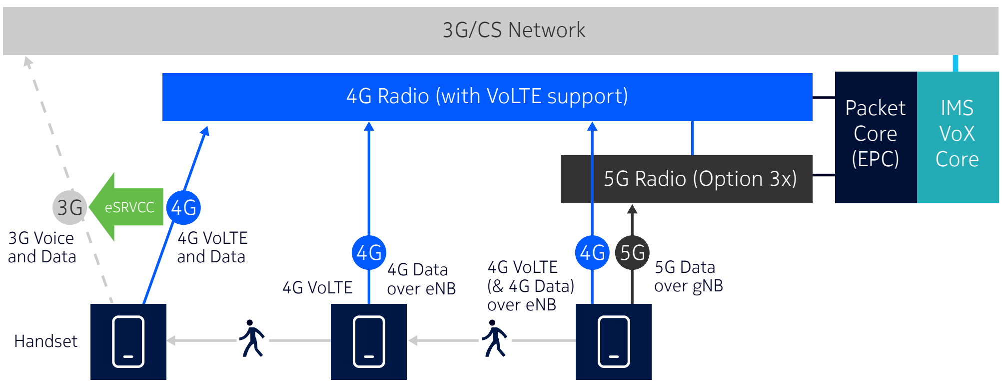
With Emergency Call Fallback the device natively operates using 5G NR. When the user initiates an emergency call, which is detected by the device, it knows that the emergency service is not supported in the current radio-core-combination. As a result, the device sends a special service request to the Access and mobility Management Function (AMF), which requests the Emergency Call Fallback from the gNB, triggering a handover to EPS and LTE. Only after the device Fallback to LTE is the emergency call initiated, meaning that the infrastructure for IMS emergency calls from LTE can be fully reused with Option 2 deployments.

# Mobility to previous generation networks

Figures 9 and 10 summarize the mechanisms used for transferring a voice call from 5G Option 3x NSA and Option 2 SA networks to existing 2G/3G/4G networks.

## For Option 3x

### Figure 9. Transferring voice calls from 5G to 2G/3G/4G networks – Option 3x

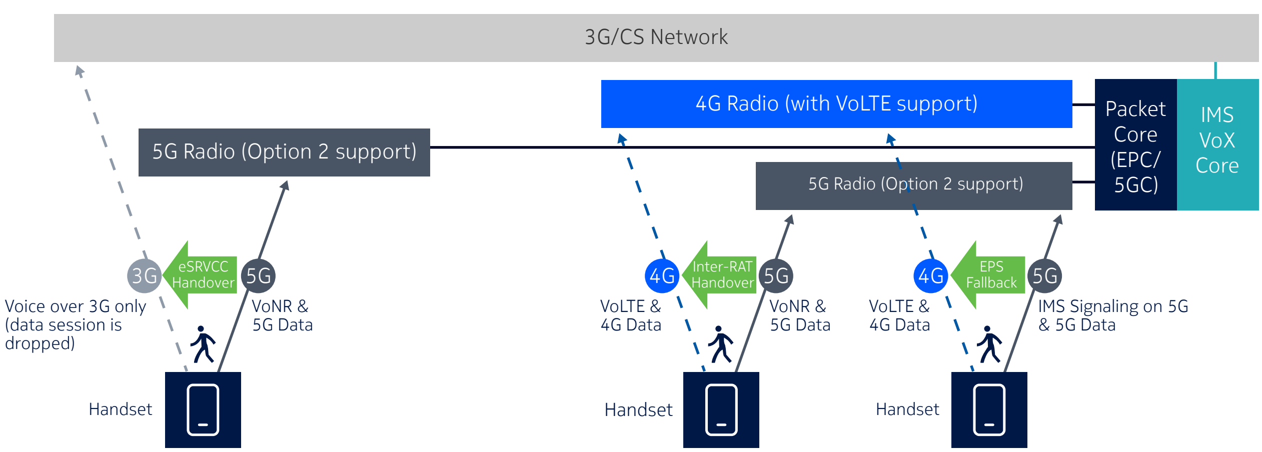



eSRVCC Handover support
- 3GPP Rel-15 supports eSRVCC domain transfer for voice and handover of data from 4G to 3G for Option 3x UE's

4G/5G Dual Connectivity UE
- 5G for high-speed Data using the Internet-APN
- 4G/VoLTE based voice services using the IMS APN
- No impact on Voice in Option 3, when the UE is losing 5G coverage and falls back to LTE
- When the 5G coverage is lost, the 5G gNB in Option 3X can keep receiving Data traffic from the EPC and forward it to the LTE eNB in order to reach the UE

## For Option 2

### Figure 10. Transferring voice calls from 5G to 2G/3G/4G networks – Option 2




SRVCC Handover from 5G to 3G
- 3GPP Rel-16 supports eSRVCC from 5G to 3G for voice only (data session is dropped)
- 3GPP Rel-15 does not provide SRVCC support from 5G to 3G: voice- and data sessions are dropped

Inter-RAT Handover 5G / 4G
- Voice over NR support
- 5G area must not be inside 4G
- Inter-Rat handover at the cell edge for both Voice & Data
- Inter-Rat Handover in both directions for voice & data

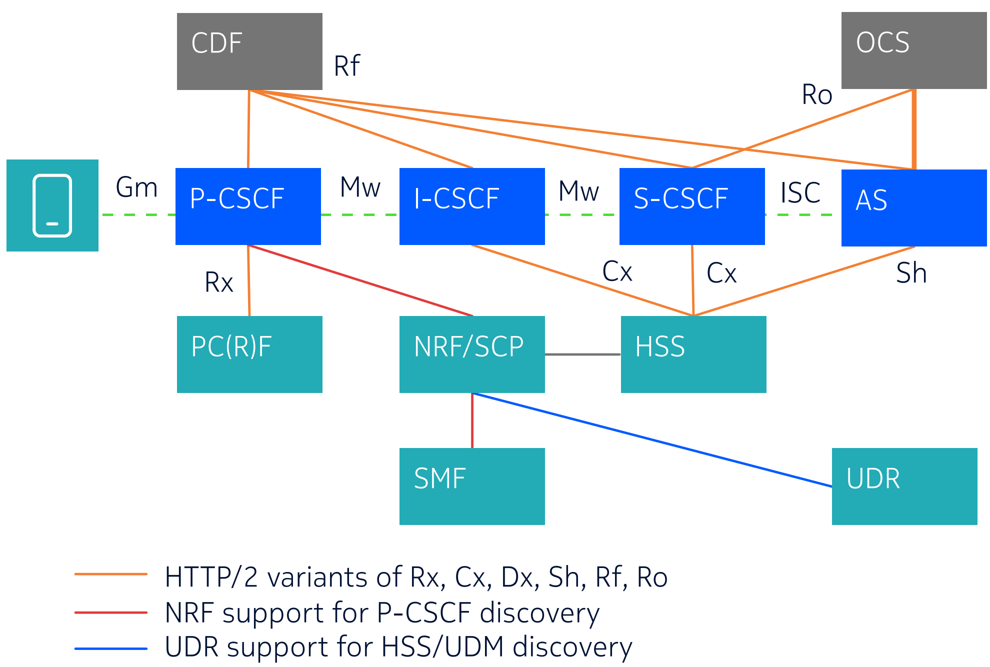
EPS Fallback 5G / 4G
- 5G area must be inside 4G
- EPS Fallback is triggered by Voice Call Setup
- Fallback of Voice & Data
- After the Voice Call is completed in 4G, the UE returns to 5G

# The evolution of IMS with 5G

With the introduction of 5G, the mobile network must continue to include VoLTE to provide voice and emergency services. The IMS used for VoLTE lays the foundations for Vo5G and CSPs that have not already done so should start introducing VoLTE as soon as possible. Also, Vo5G networks will initially use the same codecs and supplementary services as those for VoLTE.

While Rel-15 limits the modifications to IMS required to support 5G access, in Rel-16 the IMS eventually becomes part of the 5G Core and its Service Based Architecture (SBA), as shown below in Figure 11.

Figure 11. IMS in the Service Based Architecture



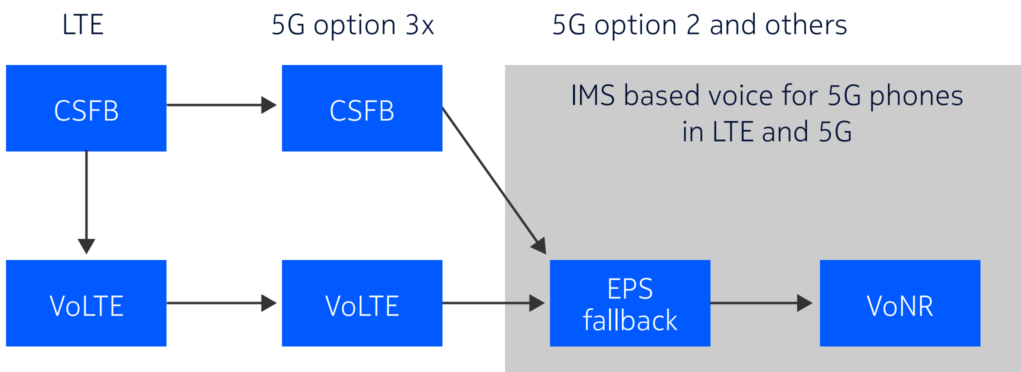

The figure illustrates the main features that are defined so far for IMS SBA support:

- The specification of HTTP/2 SBA based interface variants of the IMS interfaces Rx, Cx, Sh, and of the charging interfaces Ro and Rf, which are all currently standardized based on Diameter. See the orange lines in the figure.
- NRF support for P-CSCF discovery, where the P-CSCF registers at the NRF, such that the SMF no longer needs a statically configured list of P-CSCF addresses. Instead, the SMF can use NRF service discovery to obtain P-CSCF address information before providing that information to UEs attaching to the 5GC. This is illustrated with the red lines,
- UDR support for mapping user identities to groups of HSS/UDM instances. See the blue line in the figure.

# A migration framework for 5G

The network evolution flowchart shown below summarizes the voice call options for CSPs to evolve their current networks to support the introduction of 5G.

**Figure 12. The evolution of voice call options**




While CSPs can continue with the existing voice solution in Option 3x, Option 2 requires the use of IMS based voice for 5G devices. In particular, the introduction of EPS Fallback for 5G Option 2 requires the introduction of VoLTE for areas inside and outside 5G coverage.

# Conclusion

With the introduction of 5G Option 3x, voice services can continue either as IMS/VoLTE or as CSFB. Once the 5G Core has been introduced there are two ways to provide voice services – EPS Fallback and Voice Over NR. While Voice over NR is the desired solution, mobile phones and networks are expected to support only EPS Fallback on initial deployment of Option 2.

At this point, with the introduction of 5G Option 2, voice services for 5G users must be IMS based and the network must support VoLTE. In other words, a VoLTE solution is a fundamental requirement for introduction of the 5G Core for mobile phones.

Nokia’s VoLTE solution offers a clear evolutionary path that allows operators to take full advantage of their LTE network while working with their existing voice core.

# Frequently asked questions

**Q: Can Circuit Switched Fallback (CSFB) be used in Option 2?**

A: No, as this would require an interface between 5G Core and 3G Core, which has not been defined in 3GPP. With the introduction of Option 2, the network must support IMS based voice.

**Q: Why is it not possible to combine EPS Fallback from 5G NR to LTE with the CSFB from LTE to 3G?**

A: EPS Fallback is performed while the IMS call set-up is already ongoing, and the initial SIP invite request and the corresponding response have already been exchanged. It is too late for CSFB.

**Q: Can EPS Fallback be used in the existing VoLTE network without upgrading the existing IMS and HSS to support 5G?**

A: No – IMS and HSS need to be upgraded. In Option 2 with EPS Fallback, the IMS call set-up starts in 5G. At this time, the IMS must already support NR as a RAT type and the 5G cell identification. These are not supported by older IMS releases and, therefore, a software upgrade is required. The same applies for IMS related functionality in the HSS.

**Q: What are the reasons to use EPS Fallback rather than VoNR in Option 2 SA?**

A: Initially, NR will mainly be used in high frequency bands, which provide high bandwidth but not wide coverage. Moreover, EPS Fallback does not require the support of real time quality of service flows in phones and radio networks, thus speeding up the development and the initial deployment of 5G. In the long term, however, VoNR is the desired voice solution for 5G networks and provides the best end user experience due to the simultaneous support of voice and high-speed data services.

**Q: What about other 5G deployment options? How does voice work in Options 4, 5 and 7?**

A: The differences are transparent to the IMS. The voice solutions described for Option 2 apply to all the remaining architectural approaches, which all use the 5G Core. IMS based voice is used with or without Fallback to EPC.

# Abbreviations

| | |
|---|---|
| 3GPP | 3rd Generation Partnership Project |
| 4G | 4th Generation (mobile radio) |
| 5G | 5th Generation (mobile radio) |
| 5G Core | 5G Core |
| 5G NR | 5G New Radio |
| AMF | Access and mobility Management Function |
| AUSF | Authentication Server Function |
| CMG | Cloud Mobile Gateway |
| CS | Circuit Switched |
| CSFB | CS Fallback |
| eLTE | enhanced LTE |
| EPC | Evolved Packet Core (4G) |
| EPS | Evolved Packet System (4G) |
| eSRVCC | enhanced Single Radio Voice Call Continuity |
| gNB | 5G base station |
| GPSI | Generic Public Subscription Identifier |
| HSS | Home Subscriber Server |
| IMPI | IMS Private Identifier |
| IMPU | IMS Public Identifier |
| IMS | IP Multimedia Subsystem |
| IP | Internet Protocol |
| IT | Information Technology |
| LTE | Long Term Evolution |
| NR | New Radio |
| NRF | Network Repository Function |
| NSA | Non-Standalone |
| P-CSCF | Proxy-Call Session Control Function |
| PCF | Policy Control Function |
| PGW | Packet Data Network Gateway |
| PCRF | Policy and Charging Rules Function |
| QCI | QoS Class Identifier |
| QoS | Quality of Service |
| RAN | Radio Access Network |
| RAT | Radio Access Technology |
| SA | Standalone |
| SBA | Service Based Architecture |
| SBC | Session Border Controller |
| SDL | Shared Data Layer |
| SDM | Subscriber Data Management |
| SIP | Session Initiation Protocol |
| SMF | Session Management Function |
| SMSF | Short Message Service Function |
| SPS | Smart Plan Suite |
| SR-VCC | Single Radio VCC |
| SUPI | Subscription Permanent Identifier) and |
| TAS | Telephony Application Server |
| TCO | Total Cost of Ownership |
| UDR | Unified Data Repository |
| UDM | Unified Data Management |
| UDSF | Unstructured Data Storage Function |
| UPF | User Plane Function |
| URLLC | Ultra-Reliable Low Latency Communications |
| VCC | Voice Call Continuity |



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