VOICE AND VIDEO CALLING OVER LTE

SECURING HIGH-QUALITY COMMUNICATION SERVICES OVER IP NETWORKS
As mobile-broadband networks continue to expand, VoLTE leverages telecom characteristics such as QoS and global reach to offer innovative communication services including evolved HD voice, music sharing within a call and video communication over IP networks.
Voice services in mobile-broadband networks

Mobile broadband has created a world of opportunities and opened up new revenue streams for operators. Opportunities are often coupled with challenges, and mobile broadband tests the position of communication services, such as voice, which today account for around 60 percent of operators’ annual revenue – about USD 600 billion in 2014 – globally. The crucial question is how to take advantage of mobile-broadband opportunities, while at the same time maintaining and increasing revenues from communication services for consumers as well as for business users.

LTE networks can deliver mobile broadband with greater data capacity and lower latency. However, as there is no circuit-switched voice domain in LTE, the mobile industry has adopted a globally interoperable IP-based voice and video calling solution for LTE, known as VoLTE, which also enables development of new innovative communication services.

Over-the-top (OTT) communication solutions, such as Skype and FaceTime, have driven user adoption of more advanced service behavior based on VoIP, video-calling and messaging services in combination. However, a fully satisfactory user experience cannot be provided by OTT solutions, as there are no QoS measures in place, no handover mechanism to the circuit-switched network, no widespread interoperability of services between different OTT services and devices, and no guaranteed emergency support or security measures. Consequently, the adoption of OTT clients is directly dependent on mobile-broadband coverage and the willingness of subscribers to use a service that lacks quality, security and flexibility.

Operators have started to launch nationwide commercial VoLTE services for voice and video calling over LTE, including seamless service continuity with circuit-switched networks. In addition, continuity with Wi-Fi networks for residential use is also starting to be available on the market. With native support in smartphones and networks, a seamless high-quality experience is a given with VoLTE, and the service reach can also be extended outside LTE coverage and to additional device types.

Mobile-broadband networks will evolve into their fifth generation (5G) starting around 2020. VoLTE technology is a natural fit within 5G; VoLTE will therefore also serve as the foundation for telecom-grade voice and video calling services in future 5G networks.
A GLOBALLY INTEROPERABLE SOLUTION

LTE and Evolved Packet Core (EPC) architectures do not include support for circuit-switched voice and video calls. Two complementary tracks have emerged in the telecom industry to provide interoperable voice services in LTE smartphones: circuit-switched fallback (CSFB) (see Appendix, fact box 1) and VoLTE. Typically, CSFB is suitable for use in areas with spotty LTE coverage (in the early phases of LTE deployment or in rural areas), while VoLTE is introduced in areas of continuous LTE coverage (in metropolitan areas or in mature LTE markets).

BENEFITS OF IMS-BASED VOLTE

The term VoLTE comes from the GSMA profile for voice and SMS in LTE [1], which has its origins in the 3GPP IMS-based multimedia telephony (MMTel) solution. With VoLTE, operators can make use of the wider capabilities of IP-based networks to deliver high-capacity mobile-broadband services and launch interoperable communication services. VoLTE is a foundation for a modern user experience including services like HD voice, video calling, HD conferencing, IP messaging and contact management (as specified in GSMA’s Rich Communication Services program [2]), as well as new innovative services – all available anywhere, on any device.

VoLTE was first launched in South Korea in August 2012. Since then, a wide ecosystem of VoLTE-capable devices has developed, and operators around the world have planned for the next wave of launches. During 2014, a wider number of other operators in Asia and North America launched nationwide VoLTE services, and a large number of operators across the globe are planning to deploy them in 2014-2015.

With IMS/MMTel as the base for VoLTE, operators can evolve their voice services and add video calling – described in the GSMA specification for IMS conversational video [3]. VoLTE can leverage the world’s largest mobile user community (the Mobile Subscriber Integrated Services Digital Network - MSISDN), as well as traditional telecommunication principles such as guaranteed end-to-end QoS, support for emergency and regulatory services, global interoperability and mobility, interconnect and international roaming.
**How VoLTE Works**

Although MMTel forms the basis of the VoLTE solution, EPC (with IP flow and bearer management) and LTE (with conversational radio bearers) are integral parts of it. Together, they secure interoperability on all interfaces between devices and networks.

The majority of interface requirements are based on 3GPP Release 8. Exceptions to this include emergency voice calls over LTE and positioning services, defined in Release 9, and Access Domain Selection, based on Release 10. In general, the requirements aim to set minimum mandatory features for wireless devices and networks.

Figure 1 illustrates the importance of taking an end-to-end approach to implementation of VoLTE in order to ensure classic telecom strengths, such as excellent voice quality with QoS (LTE), mobility management (EPC), reuse of MSISDN for global voice interoperability, and various types of regulatory and supplementary services (IMS and MMTel). Details about how VoLTE works, including SMS, emergency calls, IMS centralized services (ICS) and voice handover, can be found in the Appendix.

**VoLTE Support in Smartphones**

The VoLTE device ecosystem has developed to support large-scale deployment plans with a wide set of devices from all major vendors. Devices are built using VoLTE capabilities integrated into chipsets supporting HD voice, video calling and Single Radio Voice Call Continuity (SRVCC), among others. Key VoLTE features to deliver high-quality voice and efficient capacity for the combined voice and data services are supported. Devices have been designed to adapt to radio conditions for seamless mobility, optimized battery consumption and call latency.

**Natively Integrated Wi-Fi Calling**

Natively integrated Wi-Fi calling in devices has recently been introduced by major device vendors. Operators can now extend VoLTE service reach into homes with limited cellular coverage. Seamless handover of calls from LTE to Wi-Fi is supported to ensure service continuity. The phone will use the local Wi-Fi access point and automatically connect to the operator-provided voice service via any internet connection. The native phone dialer of the smartphone is used to make regular calls, still using the SIM-based mobile phone number and without the need to use a separate app in the phone. Video calls are used in the same way.

Wi-Fi calling needs to be enabled both in the device and in the network. New integrated functionality in the EPC, with the Evolved Packet Data Gateway (ePDG), is needed to allow for untrusted non-3GPP accesses to interwork with the EPC and connect to the IMS network. The ePDG provides security mechanisms such as IPsec tunneling of connections with the device over untrusted non-3GPP access to ensure seamless handover of an ongoing VoLTE call to the user’s home Wi-Fi. The service is still anchored in the operator network via the ePDG.

Wi-Fi calling builds on IMS/MMTel and offers the same service capabilities as VoLTE, with a few differences regarding how location-dependent services are handled. VoLTE uses network mechanisms to make the service predictable and independent of load from other services, while for Wi-Fi calling, the service quality will be dependent on the local environment and load from other users connected to the same access point. Thus, Wi-Fi calling is recommended for residential usage and smaller enterprises, while larger enterprises are recommended to use 3GPP-based small cell solutions to guarantee high-quality real-time voice and video calling services.
To deliver voice services over IP-based mobile-broadband networks, it is crucial to build telecom characteristics such as QoS and utilize end-to-end tested network-to-device functionality. Voice is a real-time critical service and needs to be specially treated over mobile-broadband networks to deliver a high-quality user experience.

**VOICE QUALITY PARAMETERS**

The voice quality a user perceives is determined by several parameters, as listed in Figure 2. Several of these are the responsibility of the device alone; some rely on the network capabilities; and some are implemented in the device but affected by the network. Given that the same voice codec type (and mode) is used, there is no difference in voice quality between packet-switched networks (VoLTE enabled in LTE) and circuit-switched networks (WCDMA, GSM). The difference is that the delay parameter becomes significantly more difficult to manage. For packet-switched services, delay is the key parameter to handle in order to achieve an optimum trade-off between voice quality and voice capacity, especially on the radio network. This is why the performance of the jitter buffer manager is crucial to enable high-quality VoLTE services, since a substantial and time-varying amount of packet delay variations on the radio network have to be handled (as much as up to 80msec per link has to be handled according to 3GPP TS 23.203).

**VOICE QUALITY OF VOLTE VS OTT VOICE SERVICES**

A comparison of voice quality between VoLTE and three OTT voice services was performed by Ericsson over commercial VoLTE-enabled LTE networks in the center of Seoul in South Korea. The user-perceived voice quality of VoLTE was compared with three OTT VoIP services, and measurements were done on two different operator networks, using three different premium LTE smartphone brands.

The tests were performed both in busy hours during the day and in low network load periods during the night. The measurements were executed by drive testing, and about one hour of data was collected per service, network and smartphone brand. A drive-test tool was connected to a pair of smartphones (the same brand and model for both smartphones) during testing, and the call type was device to device. To reflect the voice quality the user perceives during a conversation, two parameters needed to be considered at the same time; an estimate of one-way listening quality (MOS-LQO), and speech path delay (SPD). Hence, these need to be presented in parallel to show the voice quality of a conversation.

1 The jitter buffer manager equalizes variations in packet delay caused by the transport network and within the nodes.
2 VoLTE was not available on one smartphone, and one smartphone was not allowed in one of the networks. Hence the number of measurements, that is, the number of square-dots in Figure 3, differs between the services measured.
3 MOS-LQO is the measurement unit used by P863 (Perceptual Objective Listening Quality Assessment, or POLQA) on wideband speech. POLQA is the ITU-recommended intrusive method for objective estimation of voice quality over packet-switched networks. The MOS scale is from 1 to 5, where 5=Excellent, 4=Good, 3=Fair, 2=Poor and 1=Bad.
Figure 3 shows the results of the measured MOS-LQO<sub>SWB</sub> and SPD during the busy hour. Per measured combination of device and network, each square-dot in the graph shows the fifth percentile MOS-LQO<sub>SWB</sub> scores (95 percent of the scores are better=higher), and the 95th percentile SPD scores (95 percent of the scores are better=lower). The dotted lines confine a gray area that illustrates where the typical targets for a high-quality VoL TE service are specified for each of the two KPIs – SPD and MOS-LQO<sub>SWB</sub>. In terms of MOS-LQO<sub>SWB</sub> the target is more than 3.5 and in terms of SPD less than 225msec. As seen in Figure 3, VoL TE exceeds those targets and none of the OTT voice services are even close.

There are two main reasons for the differences. For VoL TE, the network and the device have to pass a well-specified integration and validation procedure. Here, the specific goal is to verify that the device’s jitter buffer manager can cope with the large packet delay variations, especially around the cell border, in an LTE network. This is not the case for an OTT voice service, which results in much more variable device performance. The other major reason is that the network priority (QoS) ensures that VoL TE is delivered with telecom-grade quality (guaranteed premium service). All services may reach similar maximum HD voice MOS scores, but network priority is needed in order to get low SPD, and hence good voice communication quality.

In summary, VoL TE is a real-time telephony service managed over the operator network end to end (IMS, EPC, LTE with policy control), and the service is always prioritized over all other services. OTT VoIP services run as best-effort data services over the LTE network and are thus mixed with all other data traffic. The OTT services can thus sometimes have high quality, and sometimes very poor quality, while VoL TE offers a high and stable quality throughout the calls. Devices are also specifically designed to support inherent telephony services like VoL TE, since a number of standardization requirements have to be fulfilled, something that is not the case with OTT services.

**PERFORMANCE OF COMBINED VOICE AND DATA SERVICES OVER LTE**

While HD voice quality provides value for VoL TE users, there are other benefits to consider as well. The call setup time can be optimized to be as fast as one second, a significant improvement to the typical four-second target in circuit-switched systems. Thanks to efficient scheduling and discontinuous reception (DRX) functionality, VoL TE also features very good battery performance. With DRX, the device can be allowed to “sleep” between sending and receiving the voice packets, enabling lower energy consumption for VoL TE calls. VoL TE devices can therefore support longer talk times using VoL TE compared with OTT services and even longer than for WCDMA circuit-
switched calls.

With VoLTE, the users are not moved to circuit-switched legacy networks coverage for voice calls, and VoLTE users enjoy fast LTE data speeds simultaneously during the call. VoLTE provides high network capacity to support the migration of users from legacy systems to VoLTE, and given the design of the LTE radio interface, voice and data services can coexist seamlessly and efficiently. VoLTE call quality can also be maintained even in scenarios with high data traffic load through the built-in QoS mechanisms.

NEW VOICE CODEC FOR VOLTE – EVOLVED HD VOICE

As telecom networks are migrated to all-IP, there are possibilities to enhance voice service quality further. There is a new evolved HD voice solution for VoLTE, Enhanced Voice Service, which has recently been standardized by 3GPP. It develops HD voice even further, by providing improved voice and music quality in LTE networks [4].
The GSMA profile for IMS conversational video [5] caters for video calls over LTE based on VoLTE with the addition of video capability, providing users with synchronized full-duplex voice and video streams, as shown in Figure 4. Users can make one-to-one or one-to-many video calls, switch to video at any point during a call, and drop video at any point to continue with just voice. During call establishment, all devices involved declare their video-availability status, and the results are displayed on all devices. Users can either choose one-way video call (“see what I see”) or invite users to two-way video calls.

**GETTING CONNECTED**

A VoLTE device with video-calling capabilities performs the same network attach, IMS domain authentication and registration procedures as specified for VoLTE, with the addition of video capability information. The network can then use the video capability information to steer incoming video calls to the video-capable device.

**USE CASE AND CALL HANDLING**

A video call over LTE shares the same addressing and basic signaling rules as VoLTE. A VoLTE-and-video device can add a video component to an existing VoLTE call and later drop the video component to return to a normal VoLTE call. The MMTel service and video capability information assist the IMS network and device in several tasks, including:

- assigning the correct IMS domain MMTel application server for video-based supplementary services handling
- forking the invitation to a called device that has registered both a matching MMTel and video capability
- assisting the receiving device in launching the correct client – its VoLTE-and-video application client.

When initiating a video session, the initial signaling message contains video preference and capability information, describing the video session in detail. As for a VoLTE call, the IMS domain passes this information to the EPC for charging and policy analysis. The outcome of such analyses is the establishment of one dedicated bearer for voice and another one for video. Figure 5 illustrates the recommended flow for voice, video and signaling over three separate bearers.

When a VoLTE and video device is used to make or receive a normal VoLTE voice call, the device includes its video capability in the signaling. Each side can use this information to display to the user that the voice call can be upgraded to a video call. If one user adds video to an ongoing VoLTE call, the device sends a new invitation message with information about the additional video media component, which is treated by the IMS and EPC domains resulting in the addition of a dedicated bearer for the video stream.
While in a video session, the devices in a video call ensure lip-synchronization across the audio and video components by constantly sending timing information to each other. In addition, devices must support signaling to allow for quick response to enforced changes in video bit rate, for instance, to allow for quick picture refresh when the video signal has been switched by a network videoconferencing system. Participants using video-capable devices are able to turn off video at any time during the call and continue with voice only.

**PERFORMANCE ASPECTS OF VIDEO CALLING**

The well-established H.264 codec is mandated to secure video calling interoperability. The minimum quality level that must be supported by a VoLTE video device is the constrained baseline profile level 1.2 that offers a video bit rate of 384kbps. In early VoLTE markets, higher quality profiles are typically used running Video Graphics Array resolutions and about 500kbps video bit rates.

Even higher resolutions and bit rates will be enabled in the future by:
- the introduction of new enhanced coding technologies like H.265 (High Efficiency Video Coding) that reduce the video media bitrate by about 30 percent for a given quality level
- the ongoing densification of RANs by the introduction of new small cells and indoor systems products, and, in the not too distant future, 5G access solutions.

**VIDEO CALLING OVER WI-FI**

Seamless handover of video calls can be made between LTE and, for example, residential Wi-Fi access, if the devices support native Wi-Fi calling. This means that operators can now provide mobile video communication services to users over access systems that until now have been restricted from such use, which leads to better service coverage and QoE for users.

**VIDEOCONFERENCING**

A VoLTE video-enabled device allows its user to start videoconferences with other people at any time and in any place, as the video device is equipped with the functionality to create and participate in ad-hoc multiparty videoconferences. VoLTE video-enabled devices are also capable of participating in external videoconferences created by systems that follow the High-Definition Video Conferencing specification [6].

![Figure 5: Three bearers – for signaling, voice and video.](image-url)
The best approach to introduce voice and video calling over LTE for a given operator depends on its initial LTE coverage and deployment strategy. Operators with aggressive LTE deployment plans are likely to introduce VoLTE and video calling immediately, making it easier to evolve to richer communication services. These operators will also be able to support fixed-mobile convergence scenarios earlier.

Operators starting with spotty LTE coverage will probably deploy CSFB as a first step to avoid excessive call handovers between the circuit-switched and LTE domains. Such operators could then gradually introduce VoLTE in areas of continuous LTE coverage. Seamless service continuity with the circuit-switched domain could be offered through the usage of ICS and SRVCC (see Appendix). Seamless handover to residential Wi-Fi networks could also be used to extend reach of VoLTE services.

The SRVCC architecture in 3GPP Release 10, with anchoring of SRVCC calls in the local IMS core network, has proven that it can fulfill requirements that voice interruption time at handover be below 300msec. SRVCC functionality has been launched in commercial service by several operators.

In short, operators may evolve to LTE communication through a phased approach or take more aggressive steps – as illustrated in Figure 6.
With voice and video calling over LTE based on established telecom standards enjoying full industry support in networks and devices, operators have now started launching commercial services on a larger scale around the world. Operators have the possibility to develop their communication business, and consumers and enterprise users will benefit from richer communication services, available on any devices, anywhere. The quality of voice calls is significantly better when using telecom-grade VoLTE than any best-effort VoIP services. And globally interoperable video calling has the potential to become a next generation communication service together with even higher quality voice services and music sharing within a call. It is thus important to ensure networks are designed to handle these real-time critical services.

With the new possibility to extend VoLTE services to residential Wi-Fi access, operators could provide an even better user experience. VoLTE also builds the foundation for telecom-grade voice and video calling services in future 5G networks.

As mobile-broadband networks continue to expand, VoLTE provides a great opportunity to build a whole new telecoms world with innovative communication services over IP networks, with real and lasting value for operators, consumers and enterprise users.
CIRCUIT-SWITCHED FALLBACK
CSFB is the standardized solution for providing voice services in LTE if no IMS voice service (VoLTE) is available. When making or receiving calls using CSFB, devices are directed from LTE to WCDMA/GSM, where they remain until the call is completed. CSFB is also intended for roamers in parallel with VoLTE when no IMS (VoLTE) roaming agreement exists.

VOLTE
The VoLTE solution is defined in the GSMA Permanent Reference Document (PRD) IR.92 [7]. VoLTE is based on existing 3GPP standards and builds on IMS MMTel, specifying the minimum requirements to be fulfilled by networks and devices in order to provide a high quality and interoperable VoLTE service.

The basic scenario in the VoLTE profile assumes full LTE build-out and includes the following functionalities:

- QoS handling to guarantee a high quality MMTel service. Voice media is therefore mapped to dedicated guaranteed bitrate (GBR) bearers, and Session Initiation Protocol (SIP) signaling is protected by using a default high-priority signaling bearer.
- Mobility based on internal EPC/LTE procedures, which are transparent to the IMS/application layers.
- Advanced radio features like LTE DRX mode for terminal battery saving and robust header compression (RoHC) techniques to improve capacity and coverage.
- GSM-alike subset of MMTel supplementary services supporting a smooth evolution toward a richer communication service including multimedia capabilities.

VoLTE includes voice in full duplex, either in a one-to-one or one-to-many communication format. Figure A2 shows a simplified version of the VoLTE network architecture.

Figure A1: CS fallback.

Figure A2: VoLTE end to end (simplified view).
GETTING CONNECTED
When a device is turned on, it attaches to the LTE/EPC network and checks that the network is voice-capable. An IMS Access Point Name is then established to find the Proxy-Call Session Control Function (P-CSCF) before the device is authenticated and registered to the IMS domain (see Figure A3).

CALL AND MEDIA HANDLING
Calls are established using the SIP when an INVITE signal is sent from the device toward the network indicating the called party. The INVITE signal uses a Session Description Protocol that describes preferred media information such as which ports, IP addresses and voice coding standard – Adaptive Multi-Rate Wideband used for HD voice or Adaptive Multi-Rate Narrowband – to use. The IMS domain passes this information, via standardized interfaces, to the EPC’s policy and charging control function, which creates and installs a set of policy and charging rules in the policy and charging enforcement function (PCEF) for the received media information. The PCEF in turn performs QoS and charging-rules analysis. A typical outcome of this analysis is to establish a dedicated EPC and data radio bearer, with a GBR for VoIP media. Figure A4 illustrates SIP signaling and voice flow over a dedicated bearer.

The LTE radio network uses admission control to ensure that there are sufficient resources and capacity for the network-requested voice bearer. When the voice bearer has been established, the VoIP packets sent, using Real-time Transport Protocol, are downsized using RoHC and transported using Radio Link Control Unacknowledged Mode to minimize packet size and thus increase coverage and capacity. DRX provides low battery consumption, giving long talk time. End-to-end voice latency is on par with, or even better than, 2G/3G circuit-switched networks.

Figure A3: Registration and authentication with IMS domain across radio and EPC.

Figure A4: Signaling bearer and a dedicated bearer for voice.

SRVCC
SRVCC provides a handover mechanism between the LTE and GSM/WCDMA radio accesses. Single radio means the device transmits and receives on only one radio access at a given time in order to minimize power consumption and radio emission. SRVCC introduces the Sv-interface between the EPC and the circuit-switched core and the Mw/I2-interface between the circuit-switched...
core and the IMS core. The logical nodes Access Transfer Control Function, Access Transfer Gateway, and Service Centralization and Continuity Application Server (SCC-AS) are required in the IMS core for anchoring the control and user planes when an SRVCC handover is requested.

SMS OVER LTE

There are two options to deliver SMS services over LTE via the existing Short Message Service Center SMS-C:

- > SMS over SGs, where the device sends and retrieves native circuit-switched-based SMS messages
- > SMS over IP, where the device sends and retrieves SIP packet-switched SMS messages.

SMS over SGs transfers native circuit-switched-based SMSs via the SGs-interface between the mobile switching center (MSC) and the Mobile Management Entity (MME) and tunnels them over LTE. The device will not fall back to GSM/WCDMA while sending or receiving SMS messages as for other circuit-switched-based services provided by the SGs-interface. For SMS over SGs, the existing roaming agreements can be reused (see Figure A6).

SMS over IP transfers SIP-based SMS messages via the IMS core. The solution requires an SMS client that uses the IMS and SIP stack in the user equipment, an IP Short Message Gateway (IP-SM-GW), an IMS core and a home location register (HLR)/Home Subscriber Server (HSS) supporting SMS over IP with home routing. When the SMS recipient is being registered as an SMS over IP receiver, the HLR/HSS will respond with the address to an IP-SM-GW. The terminating SMS-C then routes all SMS messages for that subscriber to the IP-SM-GW. The IP-SM-GW then performs a domain selection procedure toward the HSS/HLR to determine if the SMS shall be delivered over IP or as a native circuit-switched-based SMS. If the SMS is to be delivered over IP, it is encapsulated in a SIP message in the IP-SM-GW. The SIP message containing the SMS is then routed to the user via the IMS (see Figure A7).
ICS
ICS is defined to make it possible for IMS to act as the single service engine for a VoLTE subscriber regardless of the access to which they are currently attached. This gives a consistent service experience and access to the full VoLTE feature set when roaming, since IMS services are always home-routed. ICS handles the situation where a VoLTE user makes or receives a call when outside LTE coverage. In a single service engine scenario, the user is still being served by IMS but connected via legacy 2G/3G access and transport.

While the 3GPP standard includes a large variety of options for performing the centralization of services into IMS, GSMA PRD IR.64 [8] focuses on two variants, of which access via unchanged MSC/media gateway control function using Customized Application for Mobile Networks Enhanced Logic home routing is currently the most widely adopted solution. The other solution is ICS with Enhanced MSC Server, which provides an UNI to IMS acting as a SIP user agent on behalf of the circuit-switched user, and is expected to be gradually introduced in the future.

EMERGENCY CALLS
Emergency calls for VoLTE can either be handled by CSFB, in which the devices fall back to overlapping GSM/WCDMA access, or within the LTE access. The best alternative depends on the radio coverage of the LTE network and the overlapping GSM/WCDMA accesses. In initial LTE deployments, the overlapping GSM/WCDMA coverage may be more reliable to use for VoLTE emergency calls. However, as the LTE network is gradually built out and tuned, it will be better to handle the emergency calls in the LTE network, as the VoLTE service will be more reliable and faster than the CSFB service. In some networks, the LTE access may use lower radio frequencies than the overlapping GSM/WCDMA accesses, and in this case, the CSFB alternative is not recommended even in initial deployments, as CSFB calls then may fail where VoLTE calls will succeed. This is because lower radio frequencies have better indoor coverage than higher radio frequencies. SRVCC is also defined for emergency calls over LTE (enhanced SRVCC) so that both SIM- and SIM-less VoLTE calls can be transferred to overlapping GSM/WCDMA coverage in case users move out of LTE coverage.
REFERENCES

5. GSMA, IR.94 IMS Profile for Conversational Video v. 6.0, op. cit.
7. GSMA, IR.92 IMS Profile for Voice and SMS v. 8.0, op. cit.
FURTHER READING

# Glossary

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<td>DRX</td>
<td>discontinuous reception</td>
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<td>EPC</td>
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<td>ePDG</td>
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<td>GBR</td>
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