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Communication services over LTE, Wi-Fi and 5G

With the accelerating global expansion of mobile broadband, the strong growth of LTE, and 5G just around the corner, the rationale for evolving today's circuit-switched voice networks to all-IP using voice over LTE (VoLTE) technology is stronger than ever. This white paper explains the technologies that enable globally interoperable communication services over any access network, using the mobile phone number as the identity on smartphones and other devices. Consumers, enterprises and vertical industries all stand to benefit from high-quality and easy-to-use voice services, as well as a range of innovative new communication services.

Introduction

According to the Ericsson Mobility Report, November 2017, the total global number of LTE subscriptions is 2.6 billion and is expected to reach 5.4 billion by 2023. The number of 5G subscriptions is forecast to reach 1 billion in 2023. Presently there are more than 125 VoLTE networks launched globally, serving around 650 million subscribers by the end of 2017. The number of VoLTE subscriptions is projected to reach 5.5 billion in 2023, accounting for more than 80 percent of the combined LTE and 5G subscriptions. As a natural consequence of increased service penetration, VoLTE roaming and IMS interconnect have started happening in Asia Pacific, North America and Europe. An increasing number of operators have publicly announced intentions to reduce and even discontinue legacy circuit-switched voice networks over a time period spanning the next five to ten years.

Over-the-top (OTT) voice services such as Skype and FaceTime have driven user adoption of more advanced communication services such as video calling and integrated messaging services. However, these solutions cannot provide a fully satisfactory user experience in many mobile scenarios because there are no Quality of Service (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. The operator-based phone number community continues to be the world's largest communication services community, and operators can leverage this asset by continuing to evolve globally interoperable services.

With native support in smartphones and aligned network functionality, VoLTE provides a seamless high-quality experience that is unrivalled by any other technology. In addition, Wi-Fi calling is natively supported in all major smartphone brands and is now being deployed in operator networks. In fact, more than 55 Wi-Fi calling networks were launched globally by end of 2017. Service continuity from LTE towards Wi-Fi networks for residential use is also possible.

VoLTE technology will also serve as the solution for globally interoperable communication services in 5G networks, which will open even greater possibilities to provide virtual and augmented reality with communication capabilities, IoT use cases between humans and machines, and other new innovative operator-based communication services use cases.

VoLTE – a foundation for a global communication services ecosystem

A standardized solution

The industry term VoLTE comes from the GSMA profile for voice and SMS in LTE [1], which is based on the 3GPP IMS-based multimedia telephony (MMTel) standard. With VoLTE, operators can make use of the wider capabilities of IP-based networks to deliver interoperable communication services over mobile broadband networks. VoLTE is a foundation for a modern user experience including services like HD voice, HD voice+ for voice and music within calls, video calling, content sharing within calls (as specified in GSMA's Rich Communication Services program [2]), as well as innovative new services – all available anywhere, on any devices that support the technology.

LTE and Evolved Packet Core (EPC) architectures do not include support for circuit-switched voice and video calls. Two tracks are available that provide interoperable voice services in LTE smartphones: circuit-switched fallback (CSFB) and VoLTE. Many operators have already deployed CSFB, especially if they had spotty LTE coverage initially. Well over a hundred VoLTE deployments have already taken place, with some also supporting video calling. The GSMA profile for video calls over LTE [3] (sometimes also referred to as ViLTE) is based on VoLTE and adds the video capability, providing users with synchronized full-duplex voice and video streams. 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. Seamless service continuity for voice with the circuit-switched domain is offered through the usage of IMS Centralized Services (ICS) and Single Radio Voice Call Continuity (SRVCC).

MMTel forms the IMS basis of the VoLTE solution, and is supported by EPC with IP flow and bearer management, and by LTE with conversational radio bearers. Together, they secure interoperability on all interfaces between devices and networks. An overview of the complete system, including devices, is shown in **Figure 1**. The entire core network (EPC, IMS, MSS and 5G Core) is now cloud enabled (NFV based) for cost-efficiency and service innovation capabilities, which enables new types of 5G use cases relating to communication services.

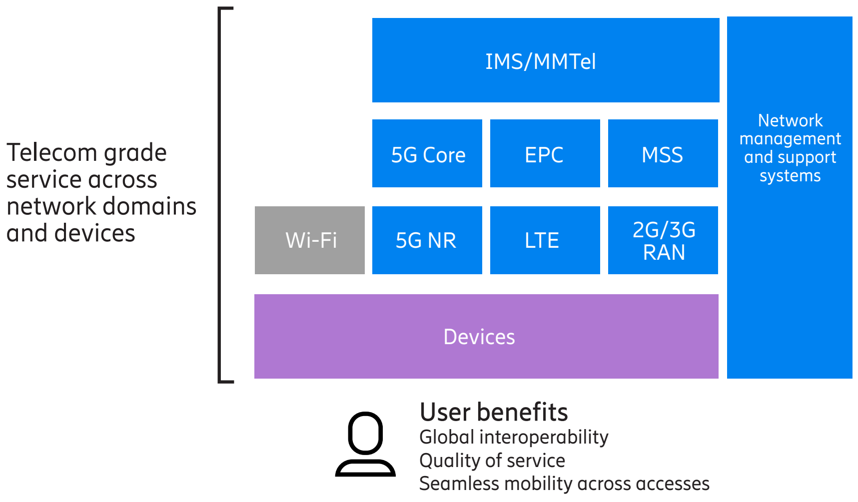

Figure 1: Overview of the telecom grade service across network domains and devices

It is important to take an end-to-end approach to VoLTE implementation to ensure the retention of classic telecom strengths such as excellent voice quality with QoS (LTE RAN), mobility management (EPC and LTE RAN), re-use of the Mobile Subscriber Integrated Services Digital Network (MSISDN) for global voice interoperability, interconnect, international roaming, and various types of regulatory and supplementary services.

VoLTE available in smartphones for all markets

The global proliferation of VoLTE-enabled smartphones continues unabated; there are already more than a thousand VoLTE-enabled models available from all major device vendors supporting different regions and frequencies. Devices are built using VoLTE capabilities integrated into chipsets supporting HD voice, HD voice+, video calling and SRVCC, among others. Key VoLTE features are supported in devices and RAN delivering high-quality voice and efficient capacity for the combined voice and data services. Devices and RAN have been designed to adapt to radio conditions for seamless mobility, optimized battery consumption and call latency.

The GSMA Open Market Devices Initiative has enhanced the VoLTE and Wi-Fi calling specifications by providing a default configuration suitable for many operators, which thus reduces device testing before market launch. The default device configuration can also be configured to operators' specific needs. Hence a consumer will be able to buy any phone and add the operator SIM card and the phone is then already or automatically configured to the specifics of the operator's network. This brings VoLTE and Wi-Fi calling technology to the same industry level as 2G/3G/LTE, where a single device can be used in many operator's networks. Consumers will benefit from an increased variety of VoLTE and Wi-Fi calling capable devices in all markets and price ranges.

Global reach enabled by roaming and interconnect

Support for VoLTE when roaming and interconnecting ensures the same rich user experience when calling users in and from other networks – that is, the user experience is not limited to calls between subscribers in the same network. In both cases the service offering and its evolution remains in the control of the home network, but the inbuilt interoperability ensures global reachability to all VoLTE networks, while ensuring connectivity to existing mobile and fixed voice and messaging users.

IMS based interconnect enables VoLTE to interoperate across operators' boundaries using HD voice and video calling. Special interworking functions may be needed on SIP level to interwork between VoLTE and fixed IMS networks, or on a functional level to ensure VoLTE KPIs are not impacted. One example is interworking for SIP precondition, which may not be supported by fixed IMS networks.

As detailed in GSMA IR.65 [4] and GSMA IR.88 [5], VoLTE roaming enables voice and video calling over LTE when roaming in partner networks. VoLTE roaming is deployed with the S8 Home Routing architecture which expands on and reuses the LTE data roaming architecture. The S8 Home Routing approach means that the voice, video calling, and messaging services are provided by the IMS in the home network while the visited network provides the connectivity, QoS, and regulatory services.

The advantage of the S8 approach is that the end users have the same services when roaming as in their home network. This means that operator-specific services and new advanced services such as multi-device and multi-persona will continue to work while roaming without cumbersome and time consuming inter-operability projects between roaming partners.

S8 Home Routing can also be deployed before a SIP Network-to-Network Interface (SIP-NNI) is introduced between operators. This aspect is also an enabler for a fast and global roaming deployment since it may take several years before SIP connectivity is deployed between all potential roaming partners.

Bringing today's voice network into the future

IP-based communication networks

Mobile networks were purpose-built for person-to-person communication first with voice and SMS, and later for mobile broadband. These networks are also used for M2M applications, various types of meters, remote control, alarms, and so on. Still these networks have built-in limitations for what can be achieved, framed by factors such as bandwidth, protocols and codec support.

Moving into IP based communication networks, a much higher degree of freedom can be applied in adopting to various application needs, connectivity and bandwidth availability, codec evolution, and new innovative devices, for example. VoLTE has not only been built to handle LTE access; the framework also supports circuit switched (CS) access through the use of IMS centralized services (ICS) and SRVCC that can be used to bridge the transition between CS and VoLTE. The principles of VoLTE can also be applied for other types of IP connectivity besides LTE, such as Wi-Fi access and future 5G networks. The introduction of NFV and network slicing in LTE core networks makes it easier to test innovations and launch new services faster. These technologies are an integral part of 5G.

With the accelerated rollout of LTE and VoLTE, operators have started the re-farming of spectrum from 2G/3G to LTE. On modern radio access platforms, this re-farming of spectrum can be achieved through software upgrades. Once all 2G/3G frequencies have been re-farmed, the current circuit switched infrastructure for telephony can be retired if it is no longer needed for the operator's own subscribers and inbound roamers.

Wi-Fi calling enabled in networks and devices

Natively integrated Wi-Fi calling in devices is now available in all major smartphone brands. Operators can thus extend voice service reach into homes and other locations with limited cellular coverage. Seamless handover of calls from LTE to Wi-Fi is supported to ensure voice 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 voice and video calls, still using the SIM-based mobile phone number and without the need to use a separate app in the phone.

Wi-Fi calling needs to be enabled both in the device and in the network. The Evolved Packet Data Gateway (ePDG) functionality in EPC is needed to allow for untrusted Wi-Fi 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 Wi-Fi access to ensure seamless handover of an ongoing VoLTE call to the user's home Wi-Fi, and vice versa. The service is still anchored in the operator network via the ePDG.

Wi-Fi calling builds on VoLTE specifications and IMS/MMTel and hence offers similar service capabilities as VoLTE, but without guaranteed QoS. There are also a few other differences related to the handling of location-dependent services. 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 suitable for residential usage and smaller enterprises, while larger enterprises are better off using 3GPP-based small-cell solutions to guarantee high-quality real-time voice and video calling services.

New use cases and more types of VoLTE enabled devices

VoLTE offers the possibility of providing operator-enabled communication services on multiple devices across all accesses, so that users can select the most suitable device for a particular occasion and even transfer ongoing calls between devices. Evolving communication services networks to IP makes it easier to extend communication services use cases to other types of devices, as shown in **Figure 2.** Functionality that makes it possible for several devices to share the same phone number is starting to emerge on the market, enabling operator voice services on tablets, smartwatches, laptops and so on. Various types of network and device solutions are available, based on different device brands' requirements and capabilities, as well as operator requirements.

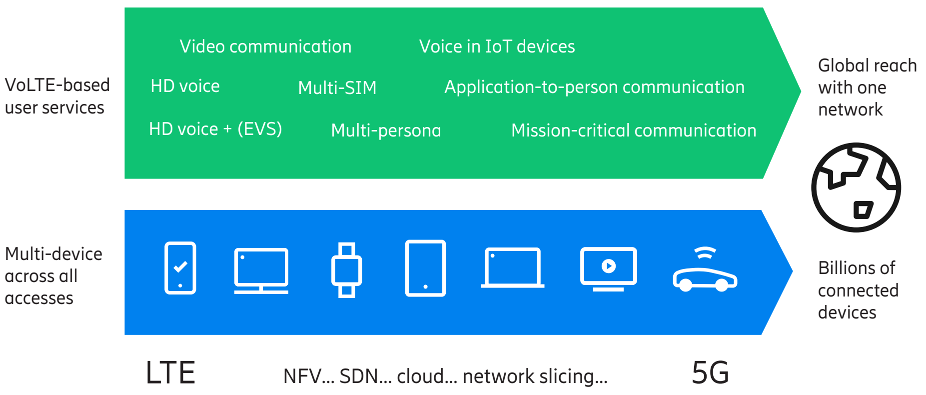

Figure 2: VoLTE-based user services – use case examples today and in the future

The next wave of multi-device support involves multi-SIM device usage – that is, the ability to share a phone number across multiple SIM devices. For example, a user may prefer to use a big screen while at work and a smartwatch when out running. The possibility to share a phone number across devices may open up a market for purpose-built devices for special workforces such as construction workers and miners. In addition, a single device can have the ability to serve multiple personas (different roles in life) – for example, one phone number for private use, another one for business, and a third when you are the rotating football coach for your child's team one day a week. Multi-device and multi-persona use cases can also be combined.

Support of VoLTE in Cat-M1 modules and network infrastructure is being enabled on the market and provides basic voice-calling capabilities for different types of IoT use cases. The VoLTE-enabled IoT devices will benefit from the characteristics of Cat-M1 modules such as form factor, long battery lifetime, coverage and low device cost. Example use cases where basic voice services could be included are alarm panels to reach service centers, wearables, digital locks, disposable security garments and more.

Depending on device type, the use cases are no longer restricted to person-to-person two-way communication – person-to-machine and one-way communication are also enabled. Use cases like immersive 3D viewing, virtual reality and augmented reality combined with operator communication services could soon be available for the mass market.

Comparing VoLTE with VoIP services

To deliver robust and reliable voice services over IP-based mobile broadband networks it is crucial to design the network with 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.

To better understand the difference in voice quality between VoLTE and OTT VoIP services, Ericsson compared their performance in commercial VoLTE-enabled LTE networks in the center of Seoul in South Korea in November 2013. These results are typically still valid for commercial networks that have been launched since. The user-perceived voice quality of VoLTE was compared with three OTT VoIP services, and measurements were carried out on two different operator networks, using three different premium LTE smartphone brands.

The tests were performed both during busy hours of the day and during non-busy hours of the night. The measurements were executed by drive testing, and about one hour of data was collected per service, network and smartphone brand. During the testing, a drive-test tool was connected to a pair of smartphones of the same brand and model, 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-LQOSWB2), and speech path delay (SPD). Hence, these need to be presented in parallel to show the voice quality of a conversation.

VoLTE outclasses the competition

Figure 3 shows the results of the measured MOS-LQOSWB and SPD during busy hours. Per measured combination of device and network, each diamond-dot in the graph shows the fifth percentile MOS-LQOSWB 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 VoLTE service are specified for each of the two KPIs – SPD and MOS-LQOSWB. In terms of MOS-LQSSWB, the target is more than 3.5 and in terms of SPD less than 225 msec. As seen in Figure 3, VoLTE exceeds those targets, while none of the OTT voice services come close.

There are three main reasons for the differences. For VoLTE, 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 second major reason is that the network priority (QoS) ensures that VoLTE is delivered with telecom-grade quality (guaranteed premium service). All services may reach similar maximum HD voice MOS scores, but network priority is needed to achieve low SPD, and hence good voice communication quality, at high network load and in cases of poor radio conditions. The third and last major reason is optimizations in the RAN, specific for real-time voice. These include mobility management where handover thresholds may be optimized for voice users to avoid exceedingly poor radio conditions, and scheduling and link adaptation techniques applicable for small packet such as voice frames, which partially mitigate poor radio conditions.

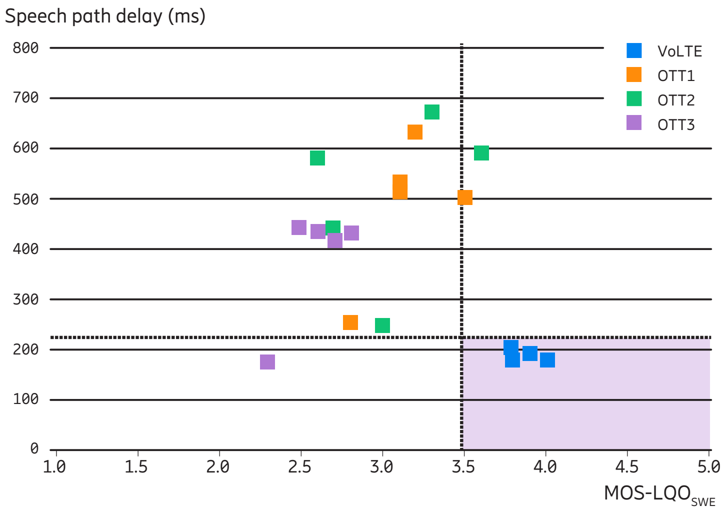

Figure 3: Voice quality test results in terms of MOS-LQOSWB and SPD for VoLTE and three OTT voice services during busy hours. The gray area represents the range for a high-quality voice service

In summary, VoLTE is a real-time telephony service managed over the operator network end to end (IMS, EPC, LTE RAN with policy control), such that the service may be 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 therefore sometimes have high quality, and sometimes very poor quality, while VoLTE offers a high and stable quality throughout the calls. Devices are also specifically designed to support inherent telephony services like VoLTE, since a number of standardization requirements like QoS and mobility have to be fulfilled, which is not the case with OTT services.

Better performance and functionality with VoLTE

While HD voice quality provides value for VoLTE 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, VoLTE 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 VoLTE calls. VoLTE devices can therefore support longer talk times using VoLTE compared to OTT services, and even longer still compared to WCDMA circuit-switched calls.

VoLTE also enables high network capacity to support the migration of users from legacy systems. 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.

As telecom networks are migrated to all-IP, there are possibilities to enhance voice service quality further. There is a new voice codec for VoLTE, Enhanced Voice Services (EVS), which is 3GPP standardized, and has a new trademarked GSMA logo "HD voice +". It improves HD voice even further, by providing improved voice and music within calls in LTE and Wi-Fi networks [6]. HD voice + provides better service quality than HD voice in good and in challenging radio conditions.

VoLTE in 5G networks

It has been agreed in the industry that 5G will use the IMS architecture and all existing IMS services. In light of this, operators that have already deployed voice and video communication over LTE and Wi-Fi can simply add the 5G NR (New Radio) and related capabilities without the need for a new solution. 5G networks will also support SMS/MMS, IP messaging and regulatory requirements related to voice and emergency calls. Also in 5G, VoLTE provides a seamless, high-quality user experience that is unrivalled by any other technology.

Different deployment options are discussed in the industry and are subject to ongoing standardization work. In an early deployment option, 5G capabilities are implemented in existing networks by adding NR as non-standalone access to the LTE radio access, with adaptation of the evolved packet core network to support 5G characteristics and capabilities. In this phase, the device may use LTE and NR simultaneously in so-called dual connectivity, but NR cannot be used standalone (Non-Standalone Access). The device may use LTE+NR and EPC for communication services as shown in **Figure 4**. The radio resource control (RRC) determines which user plane traffic (SIP and/or media) is on LTE and on NR, respectively.

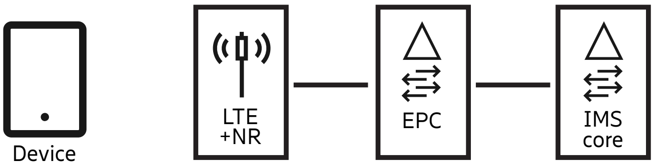

Figure 4: Communication services with LTE as standalone and NR as non-standalone access

In another deployment option (possibly as a first or as a second step), NR is provided as standalone radio access to 5G Core (5GC). Figure 5 shows the scenario where the device uses NR and 5GC for communication services. In other deployment options, LTE can be deployed as standalone radio access to 5GC, and LTE and NR can be used simultaneously in dual connectivity to 5GC.

In all 5G deployment options, the voice, video, and messaging communication capabilities of VoLTE are retained while additional capabilities are enabled. In initial deployments of NR or LTE as access to 5GC, fallback to EPS (Evolved Packet System) can be used as a technology step for voice and/or emergency calls, making it possible to use these services on EPS on the way to full voice and emergency call support in the 5G System.

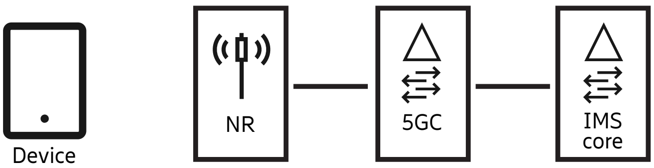

Figure 5: Communication services with NR and LTE as standalone access to 5GC

Operators investing in 5G will be in different situations regarding their coverage build-out, depending on their available spectrum. While it will take time for NR to achieve full coverage, the build-out of LTE to full coverage will be fast. The migration of all subscribers to IMS voice services reduces the need to interwork with legacy 3GPP accesses. However, deployments of 5GC must coexist and be combined with deployments of EPC. If SRVCC is required during the migration to LTE+NR in full coverage, the existing solution can be reused.

While 5G enables new possibilities for operators, legacy LTE, EPC, CS and UDM functionality will be required for inbound and outbound roamers until all networks are migrated in the same way. It can be expected that 2G and/or 3G coverage will still be in place when NR and 5GC are introduced, for roaming at a minimum, if not in HPLMN. Devices will evolve through the inclusion of additional support for 5G, including support for EPC and 5GC, and for IMS voice use cases.

With 5G access, we can expect more use cases, including interoperable communication services, based on VoLTE technology. Examples discussed in the industry include augmented or virtual reality combined with video communication, and 3D video calling.

Conclusion

Based on established telecom standards, globally interoperable communication services over LTE already enjoy full industry support in networks and devices. So far more than 100 networks have been deployed globally and VoLTE uptake is expected to reach 5.5 billion users in 2023. Operators have the possibility to develop their communication business, and consumers and enterprise users will benefit from richer communication services, available on any device, anywhere. The quality of voice calls is significantly better when using telecom-grade VoLTE than it is with any OTT voice service.

As mobile broadband LTE networks continue to expand globally, VoLTE provides a great opportunity to continue building globally interoperable communication services over IP networks. VoLTE is also the foundation for telecom-grade communication services and new innovations in future 5G networks. Combining today's high-quality voice service with new emerging use cases will provide lasting value for operators, consumers and enterprise users.

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Glossary

CS	Circuit-switched
CSFB	Circuit-switched Fallback
DRX	Discontinuous Reception
EPC	Evolved Packet Core
EPS	Evolved Packet System
EVS	Enhanced Voice Services
5GC	5G Core
5GS	5G System
ePDG	Evolved Packet Data Gateway
GBR	Guaranteed Bitrate
HD	High Definition
HLR	Home Location Register
HSS	Home Subscriber Server
ICS	IMS Centralized Services
IoT	Internet of Things
M2M	Machine-to-machine
MME	Mobility Management Entity
MMTel	Multimedia Telephony
MOS	Mean Opinion Score
MSC	Mobile Switching Center
MSISDN	Mobile Station International Subscriber Directory Number
NFV	Network Functions Virtualization
NR	New Radio
OTT	Over-the-top
P-CSCF	Proxy-Call Session Control Function
PCEF	Policy and Charging Enforcement Function
POLQA	Perceptual Objective Listening Quality Assessment
PRD	Permanent Reference Document
PS	Packet-switched
RCS	Rich Communication Services
RoHC	Robust Header Compression
SCC-AS	Service Centralization and Continuity Application Server
SIP	Session Initiation Protocol
SMS-C	Short Message Service Center
SMS over SGs	Short Message Service over SGs interface
SPD	Speech Path Delay
SRVCC	Single Radio Voice Call Continuity
UDM	User Data Management
UNI	User to Network Interface

Contributors

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