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Study Paper

on

Voice over LTE: New Voice Dynamics

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A Study Paper

1.0 Introduction

The data traffic, in telecom system, is growing at a rapid pace. However, presently for any mobile system to be commercially viable, the ability to carry voice traffic is essential. The existing 2G/3G mobile systems use "Circuit Switching" to carry voice traffic. In Circuit Switching a dedicated, end-to-end, channel or circuit is established to carry the voice traffic for the entire duration of a transmission. On the other hand, in case of IP networks, the voice traffic is carried using IP packets over data connection. For this generally "VoIP" or "VoLTE" solutions are used.

1.1 What is VoLTE

When 3GPP started designing the LTE system, prime focus was to create a system which can achieve high data throughput with low latency and at the same time has the capability to guarantee end to end Quality of Service (QoS). LTE is an all IP network and during the initial phases of its development, the ability to carry traditional service like voice was not given much importance. Therefore, for LTE networks to carry traditional circuit switched voice calls, a different solution was required. This solution to carry voice over IP in LTE networks is commonly known as "VoLTE". Basically VoLTE systems covert voice into data stream, which is then transmitted using the data connection.

In the VoLTE solution with voice services now sharing the data pipe with other data enabled services like web browsing, video streaming, and social media, the ability to manage the speed, quality and volume of data along with associated signalling is critical for providing a positively differentiated user experience. This is achievable in LTE network by way of exploiting capabilities of the IMS (IP Multimedia Sysytem) infrastructure, which provides a definite framework for ensuring end-to-end QoS for different applications including voice. Pictorially the implementation of VoLTE solution can be shown as in Figure 1.0 below.

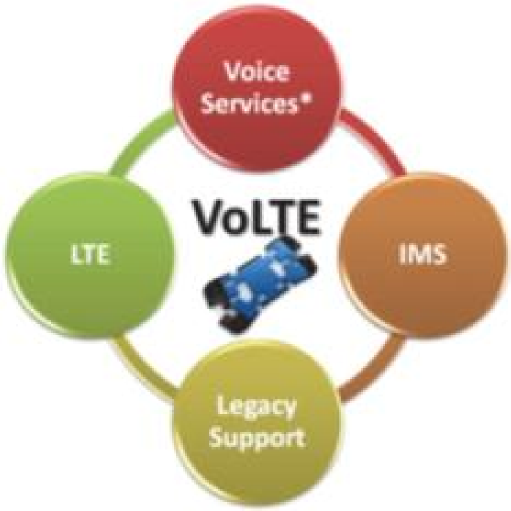

Fig 1.0: VoLTE: A combination of Technologies ***(Source: Addressing the Challenges of VoLTE Implementation by Anritsu)***

1.2 What is VoIP

VoIP (Voice over Internet Protocol) basically refers to the web based transfer of data, using IP packets, that also carries the voice traffic. In case of VoIP availability of adequate data bandwidth, for sending and receiving the voice packets to and from the network, is of prime importance to achieve desired QoS. Applications using VoIP such as Skype, Whatsapp , Gtalk, utilizing the internet on 2G and 3G platforms, have been in use since 2010. The data path used by these over-the-top (OTT) applications to carry voice is not differentiated from other IP data traffic. Therefore, the QoS for voice traffic may be severely compromised.

Therefore, the basic difference between VoLTE and VoIP is that while VoIP is best effort service, VoLTE has the capability to ensure end-to-end QoS.

2.0 Evolution of VoLTE

Originally the concept of carrying SMS and voice over all IP LTE networks, using IMS, was opposed by many operators citing the complexity of IMS as the reason. It was primarily seen to be too expensive and burdensome to maintain.

In the year 2009, 12 telecom companies including, equipment vendors, network operators and UE manufacturers proposed a solution for IMS based VoLTE. These companies included some big names like AT&T, Verizon Wireless, Nokia and Alcatel-Lucent. This initiative was called “One Voice” and the proposed solution was supposed to provide a unambiguous and common solution for voice over IP networks.

In February 2010 GSMA (Global System for Mobile Communication) took note of the solution and started to work towards standardizing this as an official solution to provide next generation voice over LTE networks. At the 2010 GSMA Mobile World Congress, GSMA announced that they support the "One Voice solution" to provide Voice over LTE. This VoLTE initiative of GSMA was subsequently supported by more than 40 organizations around the world.

In this initiative, to achieve a workable solution, a cut down variant of IMS retaining the functionality to carry the voice traffic was used. It was felt that this would be acceptable to the network operators.

In March 2010, GSMA published IR.92[1] on IMS profile for voice and short message service. This was an improved version of "One Voice" profile. In September 2010, GSMA froze the IR.92 reference document. Herein the VoLTE solution is based on the IMS MMTel.[2] concepts. The evolution of VoLTE can be depicted as in Figure 2.0 below.

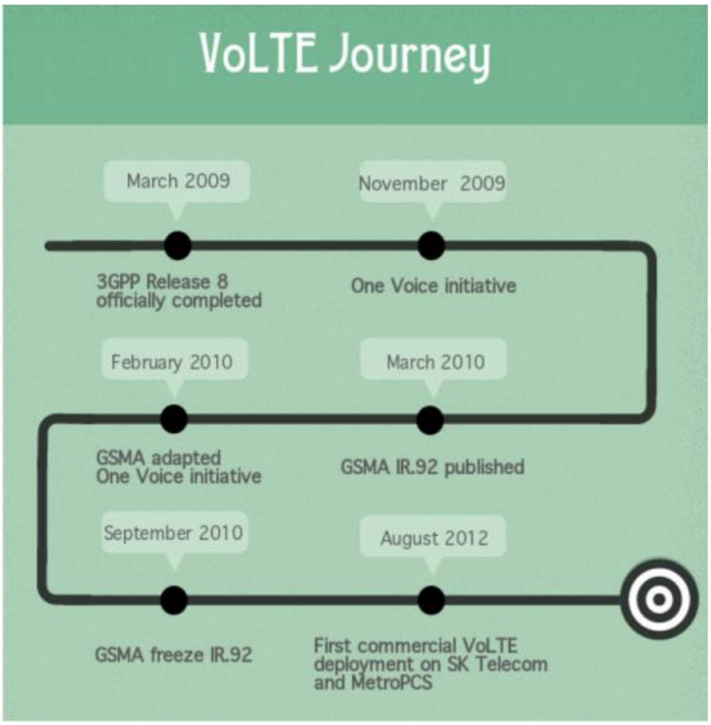

Fig 2.0 VoLTE Evolution (*Source:www.3glteinfo.com/volte-history-timeline*)

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[1] IR.92 is a document that defines voice over IMS profile by listing number of Evolved Universal Terrestrial Radio Access Network (eUTRAN), evolved packet core, IMS core, and UE features which are considered essential to launch interoperable IMS based voice services.

[2] MMTel (MultiMEdia Telephony) standard is a joint project by 3GPP and ETSI/TISPAN for delivering multimedia services like voice, video etc. over IMS. MMTel is designed for All-IP networks with support for legacy systems.

3.0 Different scenarios & mechanisms for carrying voice traffic in LTE networks:

As far as the voice traffic in data-only LTE Networks is concerned, the primary goal of the Telecom Service Providers (TSPs) is to provide telco-grade voice services. In this context, though VoLTE is ready for widespread commercial deployment, still TSPs are faced with the challenges of seamless carriage of voice traffic in different scenarios. Broadly there are two such scenarios – 1) Where the entire network is LTE but it does not have the capability to carry voice traffic. 2) Where the LTE network has the capability to carry voice but the entire network may not have LTE coverage.

3.1 Scenario 1: Where the entire network is LTE network but it is does not have the capability to make voice calls on LTE.

In such cases the voice calls are handled by the legacy networks like CDMA/UMTS(2G/3G). Here it is important to note that the deployment strategy for CDMA operators, who adopt their next generation mobile network as LTE, will be different from the network operators who migrate their network from legacy 3GPP (UMTS) networks to LTE. The deployment strategies for these two category of TSPs, over a period of time has been shown in the Figure 3.0 below.

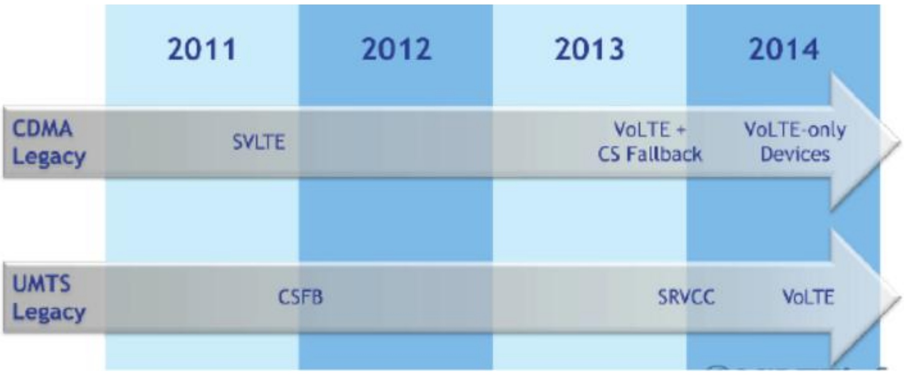

Fig 3.0: VoLTE deployment strategy (*Source: www.3glteinfo.com/volte-deployment-evolution-cs-voice-ip-lte-network*)

The two different techniques of carrying voice calls in this scenario are SVLTE and CSFB. These techniques are described below.

(i) Simultaneous Voice and LTE (SVLTE)

SVLTE allows a phone to use both voice and data networks at the same time. When LTE is used with the legacy CDMA network, SVLTE uses two different radios to simultaneously communicate with:

- Legacy CDMA network for 1x RTT circuit switched services like voice call, SMS and emergency call
- LTE network to get better packet switched (PS) data throughput

SVLTE is important because LTE networks were initially deployed to handle data only. Therefore, without SVLTE such networks will not be able to carry voice traffic as the LTE data network is as good as not unavailable for voice traffic.

Though this approach helps for rapid deployment and makes the data and voice available simultaneously but using two radio antennae is not a cost effective solution for mobile manufacturers. Also two radios may create some interference which can result in high power output. This in some cases may even exceed the permitted levels. Moreover, high power output also has direct adverse impact on battery life.

(ii) Circuit Switched Fall back (CSFB)

Circuit Switched Fall back is another feasible intermediate solution for LTE deployment voice traffic i.e. without the VoLTE solution. Due to absence of a clear voice solution in LTE during the initial phases of deployment, it was decided to opt for CSFB (CS Fall Back) as an intermediate solution. In case of CSFB if a voice call is initiated in the LTE network it is handled by the legacy networks only. When an LTE device is used to make or receive a voice call or SMS text messages, the device "falls back" to the 3G or 2G network to complete the call or to deliver the SMS text message. And thereafter when the call is released, UE reregisters back to LTE network. However, in this solution, the user experience may be an issue due to reasons which have been mentioned in subsequent paragraphs.

The biggest advantage of CSFB is that, unlike SVLTE, only one antenna is used. But with this advantage come certain drawbacks as well. For example, when UE is registered with the legacy network during the voice call it does not have access to fast services. And in some cases e.g GSM(2G), the complete PS bearer is teared down and hence the user will not be able to avail any significant data services because of the limitation of GSM network.

As an interim solution, several TSPs use CSFB for providing voice service in LTE networks prior to deployment of VoLTE solution as the preferred method. The TSPs who use CSFB as an interim solution should migrate to VoLTE at the earliest for the following reasons:

• Innovation is limited: New services that rely on all-IP networks cannot be implemented. These include video calling and WebRTC[3] .

• Customer experience is compromised:

(a) During voice calls, CSFB subscribers actually lose their LTE data service, falling back to 3G or 3G HSPA+ rates or even lose data service altogether during a fall back to 2G.
(b) In CSFB, one of the major disadvantage is higher call setup time as UE registers to 2G/3G radios networks. For example, the call set up time in CSFB on 3G is greater than 4 seconds (approximately 1 second more than the call set up time in 3G). And the call set up time in CSFB is noticeably longer than that in case of VoLTE's .

• High maintenance cost and increased business risk; TSPs have the burden to maintain and expand two networks in parallel.

3.2 Scenario 2: Where the LTE network exists along with VoLTE solution, however there may be patches where LTE coverage is not there.

In such cases the voice calls are handled by the LTE network, but if the LTE network coverage is not there at a particular place, then the calls are handled by the legacy networks. In case where there is full LTE coverage, the voice calls are carried on the VoLTE solution. In the patches where there is no LTE coverage, SRVCC technique is used to carry voice traffic. These two solutions are discussed below.

(i) VoLTE

LTE is an all IP network. The implementation of VoLTE solution to deliver voice over internet protocol in LTE network is totally dependent on IMS (IP Multimedia Subsystem).

IMS brings together voice features such as authentication, server authorisation, call control, routing, interoperability with PSTN, billing etc. These elements do not exist in Evolved Packet Core (EPC), that's why pure EPC cannot process a voice call without IMS in LTE network. In other words, in VoLTE solution, the access network is deployed via eUTRAN and EPC, while voice lies in IMS.

[3] ***WebRTC is a free, open project*** *that provides browsers and mobile applications with Real-Time Communications (RTC) capabilities*

(ii) Single Radio Voice Call Continuity (SRVCC)

SRVCC solution is used when the VoLTE calls cannot be continued due to non-coverage of LTE network. In such cases SRVCC allows a PS/IMS-based (VoLTE) Voice Call to transition to a legacy CS network.

Basically, SRVCC is a call transfer method (handover), implemented in a simplified and reliable manner used when an LTE user has an active voice session in IMS and is moving to areas which have legacy 2G/3G coverage and does not have LTE coverage. The main advantage of this solution is that the call will not drop but will only be transferred to the CS domain of the legacy networks. Further SRVCC uses a single radio, and allows an operator to provide uniform voice service, even when LTE coverage is not available. However, the signalling required is very complicated in such scenarios.

4.0 The Anatomy of a VoLTE Call

The VoLTE solution is based on two separately introduced 3GPP standards: IP Multimedia Subsystems (IMS), first introduced in 3GPP UMTS Release 5; and LTE, which was first introduced in 3GPP UMTS Release 8. It is important to mention here that neither IMS depends on the existence of LTE nor does LTE rely upon existence of IMS. Thus VoLTE can be thought of as a process that couples IMS and LTE to create an environment capable of supporting high quality voice traffic in a shared packet data network. In this combination the IMS network is the master controller for VoIP calls on an LTE network in the sense that it is the IMS that recognizes and implements the need for special network conditions required to support telco grade voice traffic.

In contrast to the circuit-switched design of 2G and 3G networks, LTE is designed as an all-IP network for the native support of packet services. It provides seamless IP connectivity between the User Equipment (UE) and the Packet Data Networks (PDNs) which deliver advanced communication services through the IP Multimedia Subsystem (IMS). A table showing comparison of downlink data speeds, under different network topologies is shown in table 1.

Generation		Technology	Maximum Download Speed	Typical Download Speed
2G	G	GPRS	0.1Mbit/s	<0.1Mbit/s
	E	EDGE	0.3Mbit/s	0.1Mbit/s
3G	3G	3G (Basic)	0.3Mbit/s	0.1Mbit/s
	H	HSPA	7.2Mbit/s	1.5Mbit/s
	H+	HSPA+	21Mbit/s	4Mbit/s
	H+	DC-HSPA+	42Mbit/s	8Mbit/s
4G	4G	LTE	100Mbit/s	15Mbit/s

Table 1: Download speeds of different network technologies

(Source: http://kenstechtips.com/index.php/download-speeds-2g-3g-and-4g-actual-meaning)

LTE provides this seamless IP connectivity while also providing improved spectral efficiency, higher bandwidth, reduced latency and the requisite Quality of Service (QoS). The LTE network is basically composed of the evolved universal terrestrial radio access network (eUTRAN) and the Evolved Packet Core (EPC).

The LTE network uses the concept of bearers to route IP traffic from the UE to the PDN. A bearer is an IP data session with a defined QoS. Besides the default bearer that is established at the time of registration of UE to the LTE network, the network also sets up and releases bearers as required by an application. These additional bearers are called dedicated bearers. The two bearers that are particularly important to carry voice traffic are:

• SIP signalling: Established when the UE's client registers with the network

• VoLTE: Established during a VoLTE call

For each bearer, the LTE network assigns a QoS Class Identifier (QCI) level. Each QCI is characterized by resource type of guaranteed or non-guaranteed bit rate, priority during congestion, packet delay budget and a packet error loss rate. These QCIs determine how a bearer is handled all the way from the UE to the PDN, including the radio resources and packet data flows. The standard QCIs are prescribed in the 3GPP standard TS 23.203.

In the VoLTE solution, the LTE network takes instructions from the IMS infrastructure using the Session Initiation Protocol (SIP). And the assigned QoS Class Identifier(QCI) establishes voice call connections with appropriate QoS. When the call has completed, the IMS directs the LTE network to tear down the special voice environment.

VoLTE Call Flow: When a subscriber turns on the VoLTE enabled device (e.g., smartphone), it connects to the LTE network infrastructure and is assigned two default EPS bearers – one for SIP signalling with a non-GBR QCI value of 5, and another for the LTE network with a non-GBR QCI value from 5-9. The QoS Class identifier (QCI) specifies the level of acceptable latency for different types of traffic. The values are specified in the 3GPP standards. The table No. 2 below compiles these values with other parameters.

QCI	Bearer Type	Priority	Packet Delay	Example
1	GBR	2	100 ms	VoIP
2	GBR	4	150 ms	Video Call
3	GBR	3	50 ms	Online Gaming
4	GBR	5	300 ms	Video Streaming
5	Non-GBR	1	100 ms	IMS signalling
6	Non-GBR	6	300 ms	Video, TCP based services e.g. mail, chat , ftp etc.
7	Non-GBR	7	100 ms	Voice video gaming
8	Non-GBR	8	300 ms	Video, TCP based services e.g. mail, chat , ftp etc.
9	Non-GBR	9	300 ms	Video, TCP based services e.g. mail, chat , ftp etc.

Table 2: LTE QCI values as per 3GPP standard TS 23.203

This dual-bearer approach allows a VoLTE smartphone to communicate in the languages of both LTE and IMS (SIP). A typical, step by step, VoLTE call flow is described below and the same has also been depicted in Figure No.4.0

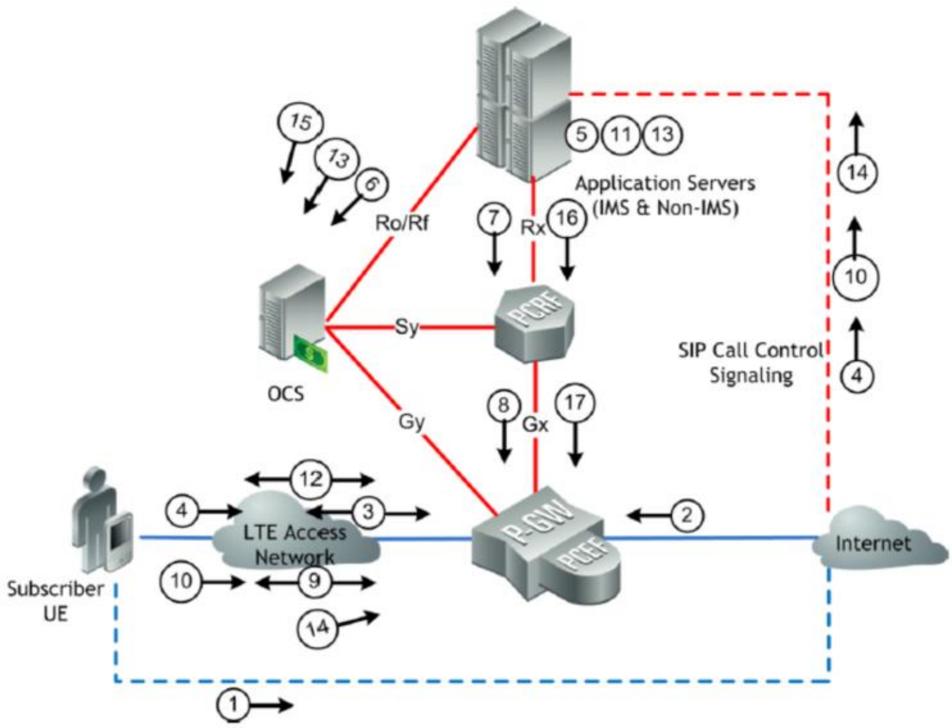

Fig 4.0: VoLTE call flow
(Source: www.sandvine.com/downloads/general/whitepapers/volte-challenges-and-opportunities.pdf)

1. The mobile subscriber indicates on their LTE-enabled smartphone the desire to make a VoIP call.

2. LTE identifies a Packet Data Network (PDN) Gateway (P-GW) that offers a connection to the IMS network.

3. LTE establishes a Default bearer for SIP from the subscriber to the selected P-GW. The default EPS bearer is established with a QoS Class Identifier (QCI) value of 5 (the QCI value required for SIP signalling).

4. The smartphone sends a SIP "Invite" message toward the IMS network. Contained in the SIP message is a Session Description Protocol (SDP) that carries the QoS requirement. Although SIP messages are carried through the LTE network, the LTE network is unaware of the content of the message.

5. The IMS network extracts the required QoS setting from the SIP message.

6. If a charging policy applies, then the IMS network sends an initial diameter Credit Control Request (CCR) to the Online Charging System (OCS) over the Ro interface and an initial

amount of credit is reserved anticipating the need to precisely meter flow of data during the call.

7. The QoS requirement is sent from the IMS network through the Rx interface (using the Diameter protocol) to the Policy Control and Charging Ruling Function (PCRF).

8. The PCRF creates actionable charging and QoS rules and forwards these across the Gx interface to the Policy and Charging Enforcement Function (PCEF) that lives with the P-GW in the LTE network.

9. The P-GW now sends a request to establish a separate “dedicated bearer” (with a QCI value of 1) to the smartphone.

10. After the smartphone confirms that LTE can support the new dedicated bearer, it sends a SIP “UPDATE” message to the IMS network.

11. The IMS network completes the setup process and establishes the call.

12. Bidirectional VoIP call packets flow inside the LTE network (to the P-GW) and smartphone

13.For charging, the IMS network requests credit from the OCS throughout the call (e.g., every 10 seconds). If credit does not exist, a 402 (payment required) message is sent back to the smartphone and the call is cancelled. If credits expire during the call, it is terminated.

14. When the call terminates, the smartphone sends a SIP “BYE” message to the IMS network.

15. The IMS network sends a diameter CCR termination request to the OCS, which ends the charging metering and triggers actions to collect IMS billing records.

16. The IMS network notifies the PCRF of call termination.

17. The PCRF tells the PCEF to close out the LTE billing, and instructs the P-GW to tear down the dedicated bearer established for the VoIP call.

4.1 **IMS architecture in VoLTE call set up**

For implementation of VoLTE, a cut down version for IMS was defined for VoLTE. This not only reduced the number of entities required in the IMS infrastructure, but it also simplified the interconnectivity by focussing on the elements required for VoLTE. The Figure No4.1 below shows the cut down version of the IMS used in VoLTE solution.

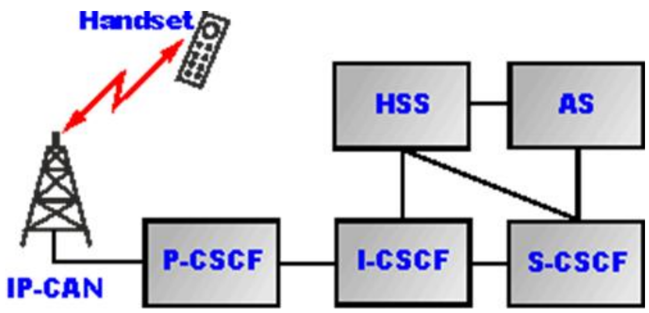

Fig 4.1: Reduced IMS network for VoLTE (*Source: www.sandvine.com/downloads/general/whitepapers/volte-challenges-and-opportunities.pdf*)

As can be seen, the following entities are required within the reduced IMS network for VoLTE solution:

- ***IP-CAN IP, Connectivity Access Network:*** This consists of the EUTRAN and the MME.
- ***P-CSCF, Proxy Call State Control Function:*** The P-CSCF is the user to network proxy. In this respect all SIP signalling to and from the user runs via the P-CSCF whether in the home or a visited network.
- ***I-CSCF, Interrogating Call State Control Function:*** The I-CSCF is used for forwarding an initial SIP request to the S-CSCF. When the initiator does not know which S-CSCF should receive the request.
- ***S-CSCF, Serving Call State Control Function:*** The S-CSCF undertakes a variety of actions within the overall system, and it has a number of interfaces to enable it to communicate with other entities within the overall system.
- ***AS, Application Server:*** It is the application server that handles the voice as an application.
- ***HSS, Home Subscriber Server:*** The IMS HSS or home subscriber server is the main subscriber database used within IMS. The IMS HSS provides details of the subscribers to the other entities within the IMS network, enabling users to be granted access or not dependent upon their status.

The IMS calls for VoLTE are processed by the subscriber's S-CSCF in the home network. The connection to the S-CSCF is via the P-CSCF. Depending upon the network in use and overall location within a network, the P-CSCF will vary.

4.2 VoLTE codecs

As with any other digital voice system, codecs are used in VoLTE too. The codec that is specified for VoLTE, by 3GPP, is the adaptive multi-rate (AMR) codec that is also used in many other cellular systems such as GSM, UMTS etc.. The AMR-wideband codec may also be used.

The use of the AMR codec for VoLTE also provides advantages in terms of interoperability with legacy systems. No transcoders are needed as most legacy systems now are moving towards the AMR codec.

In addition to this, support for dual tone multi-frequency, DTMF signalling is also mandatory as this is widely used for many forms of signalling over analogue telephone lines.

4.3 VoLTE IP versions

With the update from IPv4 to IPv6, the version of IP used in any system is of importance. VoLTE devices are required to operate in dual stack mode catering for both IPv4 and IPv6.

If the IMS application profile assigns any of the IPv4/IPv6 address, then the device is required to prefer that address and also to specifically use it during the P-CSCF discovery phase.

One of the issues with voice over IP calls is the overhead resulting from the IP header. To overcome this issue VoLTE requires that IP header compression is used along with Robust Header Compression (RoHC), the protocol for compressing voice data packet headers.

5.0 Benefits of having voice through VoLTE

VoLTE offers a number of benefits both for the subscribers as well as the TSPs. An independent research has been done by study by ABI (a Signals Research Group) to analyse VoLTE performance in a commercially deployed network. The research evaluated the parameters like call setup time, reliability, quality, network resource requirements, battery life etc. The significant findings are as under:

• VoLTE call quality greatly exceeded that of 3G circuit-switched voice and was measurably higher than the HD voice service offered by Skype.

- VoLTE supports the wideband advanced multirate codecs that enable the next level of evolution of the phone call, that is, high-definition (HD) voice

• With network loading i.e., lots of competing traffic, and in particular with background applications running on the mobile phone exchanging data with the network, the VoLTE results were considerably better than Skype

• VoLTE call setup time was nearly twice as fast as 3G Circuit Switched Fallback (CSFB) call setup

• VoLTE used substantially fewer network resources than Skype voice, which in turn resulted in longer estimated device battery life for the subscriber and a more efficient network for TSPs

• When leaving LTE coverage, VoLTE calls were successfully handed over to 3G or 2G circuit-switched voice, ensuring call continuity without interruption. Whereas this was not the case with VoIP on other OTT Applications. Therefore, with VoLTE while the subscribers benefit from better Quality of Service and improved device battery life, the TSPs enjoy greater delivery efficiency.

So deploying VoLTE in LTE netwok offers a number of benefits for both, the Customers as well as the TSPs. These are summarized as under:

5.1 Advantages of VoLTE from customer's point of view

For the Customers, VoLTE offers a number of benefits. Some of these benefits are mentioned below:

- Call set-up time: In case of VoLTE call set-up time is 1-2 seconds, while in case of circuit switching, the UMTS/GSM layer typically takes 5-10 seconds.
- Sound quality: The highest possible bit rate can be defined in VoLTE. Currently, the global voice standard supports AMR-WB codec at 23.85 kbps, which is HD voice.
- Battery life: VoLTE sessions require significantly less power because the processing happens on the baseband processor or modem rather than on the application processor. Moreover, as the call set-up time is less with VoLTE, the battery life of the user device is increased by 15-20 per cent on this account only.
- Sessions: Simultaneous voice and data connections are achieved through the shift to VoLTE. It also has the potential to be combined with rich media services.
- Multimedia services: VoLTE enables multimedia content sharing during voice calls, SMS over IP, video calls and video sharing.

5.2 Advantages of VoLTE from TSPs point of view

For the TSPs, VoLTE offers a host of marketing and operating advantages. Some of these are enumerated below:

- Reduced cost and complexity of network because a single all IP network carries voice, video and other data services.
- Enhanced user experience which could lead to ARPU augmentation.
- Capability to support rich multimedia applications like HD voice which can help TSPs market the services in a better manner.
- Efficient spectrum utilisation provides opportunities for Opex savings from consolidation and optimisation.
- The rich communication suite support in VoLTE, enables TSPs to compete with OTT Service Providers as they can offer a host of services like rich voice and messaging services including SMS, Instant Messaging, group chat, live video sharing and file transfer etc.

6.0 Potential of VoLTE : Global Trends

Globally, as wireless data traffic continues to grow, TSPs have focused on deploying the more efficient LTE networks. The 4G smartphone ecosystem has also evolved rapidly and latest smartphones sold in developed markets operate on 4G (LTE) networks. Availability of network and devices has led to rapid growth in 4G subscribers.

The number of VoLTE subscribers is on the rise as carriers launch commercial VoLTE networks and services. A total 23 VoLTE networks were launched worldwide in 2016, bringing the estimated cumulative total to 63(Source: IHS Technology and the Global Mobile Suppliers Association (GSA)).

As per the history of VoLTE deployments across the globe on Wikipedia (https://en.wikipedia.org/wiki/Voice_over_LTE#Deployment) , details of some of the commercial VoLTE deployments around the world are as under

- In May 2014, Singtel introduced the world's first commercial "full-featured" VoLTE service in Singapore, only in combination with the Galaxy Note 3
- In June 2014, KT showcased the world's first cross-border roaming services based on VoLTE. The South Korean operator partnered with China Mobile to develop VoLTE roaming services.

- In November 2014, Verizon and AT&T announced that these companies are enabling VoLTE-to-VoLTE connections between their respective customers. VoLTE interoperability between Verizon and AT&T customers began in 2015.
- On 11 July 2015, SEATEL Cambodia announced the world's first commercial 100% VoLTE service without 2G/3G in Cambodia.
- On 16 September 2015, Telstra, Australia announced that it had started enabling VoLTE across its network, including calling to National Broadband Network and business and enterprise services with HD handsets.
- On November 30, 2015, Telenor Denmark launched VoLTE for all Samsung Galaxy S6 phones, which has since been followed by additional Samsung and Apple models.
- On June 30, 2016, YTL's YES launched 4G LTE service to become Malaysia's first VoLTE service provider.
- **Reliance Jio announced commercial launch of 100% VoLTE service in India on 5th Sep 2016.**
- In October 2016, Orange Polska launched commercial VoLTE service in Poland.
- In November 2016, T-Mobile (Poland) launched commercial VoLTE service in Poland.
- On December 07, 2016, Telenor Denmark launched VoLTE for all phones with VoLTE support.

Commercial deployments of LTE networks worldwide are pre-requisite for successful deployment of VoLTE. According to data released in a report 'Evolution to LTE Report-January 2017 released by GSA (Global mobile Suppliers Association representing GSM/EDGE/WCDMA-HSPA/HSPA+, LTE/ LTE Advanced and future 5G suppliers) -

- ✓ 581 LTE, LTE-Advanced networks have been commercially launched in 186 countries
- ✓ A total 102 operators have launched VoLTE-HD service in 54 countries
- ✓ 7,037 LTE user devices have been announced
- ✓ 790 operators are investing in LTE across 201 countries.

The total of global VoLTE subscribers is forecast to reach 1 billion by 2020, up from 185 million in 2015 and worldwide VoLTE services revenue is forecast to rise to $6.3 billion by 2020, with North America, where ARPUs are highest, accounting for nearly half (Source:IHS Technology's 2016 VoLTE Services & Subscribers Market Report.). Therefore, it may be inferred that VoLTE has a tremendous growth potential.

7.0 Roadblocks and challenges across the way of VoLTE deployment:

The major challenge in the implementation of VoLTE will be to set up the infrastructure necessary for enabling seamless service. This part explores the various challenges faced by TSPs in deploying VoLTE enabled networks. Some of these important challenges are enumerated below:

- Testing of end-to-end IMS signalling over the LTE radio access network because of over 10-fold increase of signalling load on the control plane and PCRF element as it mandatorily specifies the QoS for every single voice call passing through the LTE network. When one considers, in addition, the non-voice application services such as video streaming, online gaming etc. the signalling load increases further.
- Ensuring Seamless mobility between packet switched and legacy circuit switched networks in a manner that ensures that the voice calls operate with no discernible effect on the user's experience when moving from one network to another.
- Complying with standards to ensure global interoperability.
- Adherence to regulatory requirements such as emergency calls etc.
- Rapid evolution of the device ecosystem to support VoLTE functions seamlessly.
- VoLTE device interoperability challenges such as:
    - different EPS bearer setup
    - proprietary simplification of SIP call flows
    - operator specific introduction of SIP headers
    - different security configuration
- Maintaining Call Quality as Customers expect at least same user experience in VoLTE as they have experienced from the legacy CS-Voice.
- Implementation of IMS/VOLTE is much more proprietary and varies from device to device, e.g. device behaviour when receiving SIP error message and device behaviour when LTE connection is lost etc. may vary with device.

7.1 VoLTE deployment in India: challenges

It is important to note that Indian TSPs invested significantly in 3G network and spectrum from 2010 to 2015. The slow uptake of 3G in India means a lot of that investment has not yet been fully recovered.

So the question arises whether the Indian market will support both 3G and 4G networks and what does the future holds for 3G networks once 4G gains traction. When it comes to the postdeployment phase in India, a VoLTE operator could be faced with lack of network continuity, both intra and inter-operator. Therefore, until an operator has deployed VoLTE across all its Licensed Service Areas, subscribers' VoLTE experience would remain limited within the coverage areas of select cities. The lack of Pan-India broadband wireless access spectrum is also a significant challenge for enabling seamless roaming across India.

IMS provides the framework to support VoLTE, the lack of deployment of IMS infrastructure in the country is another important challenge that most Indian TSPs are facing. This fact is also preventing them from leveraging their LTE assets fully. Due to this limitation, TSPs need to rely on circuit switched fall-back technology to support voice calls. Currently, the Indian market is in the trial phase for both LTE and VoLTE. However, the LTE and VoLTE adoption curve is predicted to be faster than that of 3G.

8.0 Conclusion

The Indian telecom industry is still awaiting the full implementation of LTE technology. With 3G services struggling to reach the masses in the country, leveraging the distinct advantages of VoLTE could be some time away for the Indian market. If TSPs fail to develop and implement solutions that will allow voice traffic to be carried over LTE networks, they will have to maintain legacy networks for voice communications. This will restrict them from exploiting the superior spectrum utilisation and cost efficiency that LTE offers over legacy technologies.

As the TSPs plan VoLTE deployment, they have to take care that the stringent metrics necessary for commercial mobile voice are guaranteed. VoLTE is a new mobile voice and it has tremendous value and offers a lot of potential to the TSPs in terms better business strategies and marketing of services. However, on a note of caution it is worthwhile to mention that it is a critical service that requires phenomenal expertise to ensure quality of mobile voice that meets or beats quality of voice carried over legacy networks.

ACRONYMS

2G	Second-generation wireless, such as GSM
3G	Third-generation wireless, such as UMTS /WC DMA
3GPP	Third Generation Partnership Project
4G	Fourth-generation wireless, such as LTE
AP I	Application Programming Interface
ATC F	Access Transfer Control Function
ATGW	Access Transfer Gateway
CAMEL	Customized Applications for Mobile Enhanced Logic
CDMA	Code Division Multiple Access
CS	Circuit-switched
CS FB	Circuit-switched fallback
eNodeB	Evolved Node B
ETSI	European Telecommunications Standards Institute
EPC	Evolved Packet Core
eSR -VCC	Enhanced Single Radio – Voice Call Continuity
eUTRAN	Evolved Universal Terrestrial Access Network
GBR	Guaranteed bit rate
GSM	Global System for Mobile communications
GSMA	GSM Association
HD	high definition
HSPA +	Evolved High-speed Packet Access
HSS	Home Subscriber Server
ICS	IMS Centralized Services
IMS	IP Multimedia Subsystem
IN	Intelligent Network

IP	Internet Protocol
IPX	IP exchange carrier
LTE	Long Term Evolution
MME	Mobility Management Entity
MMTel	Multimedia Telephony
MSC	Mobile Switching Centre
OTT	over-the-top provider
P2P	peer-to peer
PCEF	Policy and Charging Enforcement
PCRF	Policy Control and Charging Rules Function
PDN	Packet Data Network
PGW	PDN Gateway
PR D	Permanent Reference Document
PS	packet-switched
QCI	QoS Class Identifier
QoS	Quality of Service
RCS	Rich Communications Suite
RCS e	Rich Communications Suite – enhanced
RFP	Request for Proposal
SGW	Serving Gateway
SIP	Session Initiation Protocol
SMS	Short Message Service
SR -VCC	Single Radio - Voice Call Continuity
SV -LTE	Simultaneous Voice and LTE
TCP	Transmission Control Protocol
TISPAN	Telecoms and Internet Converged Services and Protocols for Advanced Networks

UE	User equipment, such as a smartphone
UMTS	Universal Mobile Telecommunications System
VoIP	Voice over IP
VoLTE	Voice over Long Term Evolution

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