

VoIP on 3GPP LTE Network: A Survey

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Abstract
As wireless access networks evolve towards an all-IP architecture, the principles of operations of communication services (specifically voice services), which have hitherto been circuit switched are being revisited. Voice over Internet Protocol (VoIP) has been identified as a solution and is potentially capable of completely replacing existing phone networks. However, as opposed to circuit switching technology, the call quality obtained via packet switching through IP has not been encouraging due to certain issues. The increasing demands on data rates, mobility, coverage and better service quality, led to the evolution in Radio Access Technologies (RATs) to an era of last-mile fourth generation (4G) access technologies among which is Long Term Evolution (LTE). LTE is an all-IP network initially meant for carrying data only, while carriers would be able to support voice traffic either by utilizing 2G or 3G systems or by using VoIP. This paper seeks to describe all options for providing VoIP services as a method of voice transfer over the LTE network.
Keywords: 4G, Circuit switching, Convergence, LTE, Packet switching, RAT, VoIP.

1. Introduction

The Internet Protocol (IP) is the driving force for future communication networks with convergence being an important requirement. Voice over IP (VoIP) can be said to have contributed somewhat to this convergence such that multiple networks including data, voice and video, are being integrated into a single network to share common facilities resulting in efficiency and cost savings; therefore, it has the potential to completely replace existing phone networks.

However, as opposed to voice service through circuit switching technology, the quality of calls transmitted via packets through internet protocols was still not very encouraging; therefore, its use by operators and consumers was still limited. This was majorly due to the fact that voice transmission demands high-speed data rates for effective and efficient communication, which was a scarce and expensive commodity. To enhance the user Quality-of-Experience (QoE), necessary Quality-of Service (QoS) measures were developed and implemented. The QoS measures addressed issues peculiar to packet networks such as but not limited to packet loss, latency, jitter and echoes in the network.

These issues brought about the necessity for multiple networks: circuit switching network for voice and packet switching network for data. This led to high CapEx (Capital Expenditure) and OpEx (Operating Expenditure), in that, the separate networks needed separate infrastructure and running expenses.

The increasing demands on data rates, mobility, coverage and better service quality, led to the evolution in RATs and the corresponding Radio Access Networks (RANs) from the eras of second generation (2G) systems (a mixture of circuit switching and packet switching functionalities) through till the advent of last mile fourth generation (4G) access networks which are entirely packet-switched. These 4G RATs, which are entirely packet-based, are foreseen to either complement or replace existing standards because the required future RAN architectures must support an increased volume of packet-based applications, ensure availability of efficient IP packet transport, and provide mobility within and between the access networks (Didier, 2007; Jordi, 2007; 3GPP2, 2006).

The introduction of a Next Generation Mobile Broadband Network (NGMBN) called Long Term Evolution (LTE) falls into this 4G all-IP category. LTE, developed by 3GPP (ETSI TS, 2011), builds on the UMTS cellular technology to meet operator requirements for high-speed data and other multimedia transport as well as high-capacity voice support for future generations. It possesses the strength and capabilities to support real-time applications excellently well (like in voice transfer using VoIP).

LTE at the onset, was understood to be a completely IP cellular system meant for carrying data only, while carriers would be able to support voice traffic and SMS either by utilizing 2G or 3G systems or by using VoIP. Consequently, a number of alliances were set up to develop approaches in ensuring the possibility of carrying voice over the LTE network (Ian, 2012).

This paper seeks to describe all options for supporting VoIP services as a method of voice traffic over the LTE network and it is organized as follows:

Section II describes briefly the principle of operation of VoIP. Section III describes the components and functionalities in an LTE network. Section IV explores the various options for VoIP services over an LTE network. Section V highlights the benefits of carrying voice over LTE through VoIP. Finally, Section VI gives a summary on the subject matter as well as likely future trends.

2. Voice over Internet Protocol (VoIP)

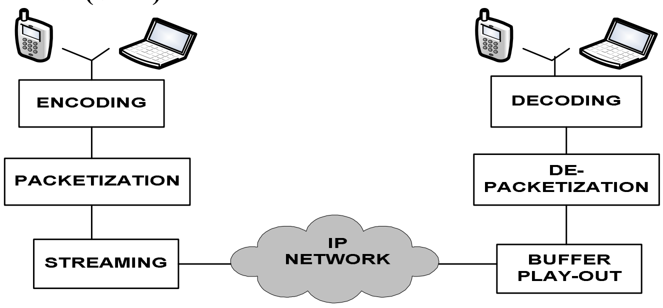

Fig. 1: VoIP Architecture

As summarized in Figure 1, after establishment of the call using a signaling protocol, the analogue input speech signal is converted into a digital bit-stream using a coder-decoder or compression-decompression algorithm which is selected depending on the desired output characteristics. The encoded speech is then broken down into packets which contain information about the packet's origin, its intended destination and a timestamp that will ensure the packet stream is correctly reconstructed at the receiver. The packets are transmitted over a packet-switched network via protocols which do not guarantee QoS during the call; therefore, other protocols are introduced, to procure some level of service reliability. At the receiver, the packet stream goes into a buffer play-out in which attempts are made in restoring the original timing of the packets to the extent possible since the organization of packets is of no relevance to the transport protocol used. The stream is then de-packetized and decoded such that it makes sense to the human ear.

3. Long Term Evolution (LTE) Overview

LTE was developed and standardized by 3GPP as Release 8 which builds on 3GPP GSM/UMTS and uses E-UTRAN (Evolved-UMTS Terrestrial Radio Access Network) as its radio access and is therefore sometimes referred to as E-UTRAN (Freescale Semiconductor Inc, 2008). LTE is an exit from previous long-standing cellular and telecom networks, which were circuit switched/circuit and packet switched to an all-IP and packet based network which is the first amongst the 3GPP generation of standards.

3GPP LTE is a significant advance in cellular technologies. The major goals of LTE are to reduce the system and User Equipment (UE) complications, allow flexible spectrum distribution/deployment in existing or new frequency spectrum and to enable cross-functionalities with other 3GPP RATs.

3.1 LTE Key Benefits

The key benefits/features of LTE as outlined by the UMTS Forum (UMTS Forum, 2008) are as follows:

1. Enhanced air interface supporting increased data rates: It is built on a newly evolved RAN based on OFDM (Orthogonal Frequency Division Multiplexing) technology, allowing increased theoretical data rates of up to 300Mbps on the downlink and 75Mbps on the uplink for its variable channel size with a maximum of 20MHz. The air interface of LTE uses OFDMA as its modulation and multiple access techniques on the downlink and SC-FDMA (Single Carrier Frequency Division Multiple Access) on the uplink. The LTE access network also incorporates higher order modulation schemes alongside advanced antenna techniques like MIMO to enable efficient utilization of its RF spectrum.
2. Enhanced Spectral Efficiency: LTE provides operators with the opportunity to accommodate increased number of customers within their existing and future spectrum allocations with a reduced cost per bit, due to highly improved spectral efficiency.
3. Flexible radio planning: LTE can deliver excellent performance in a cell size of up to 5 km. It has the capability of delivering acceptable and effective performance in cell sizes of up to 30 km radius, and provides a limited performance in cell sizes up to 100 km radius.
4. Reduced Latency: LTE RAN reduces round-trip time to 10ms or even less; therefore, it has the capability to deliver a more responsive user experience. This allows for interactive and real-time services such as high-quality audio/videoconferencing and multi-player gaming.
5. The LTE access network supports several options for frequency bands, duplexing techniques and carrier bandwidths to ensure effective utilization of the different aspects of unused spectrum in different countries and geographies (Per, 2007); which enhances mobility/roaming.
6. An all-IP network: LTE presents a flat, all-IP simplified network architecture with open interfaces. This marks a reflection of the target of 3GPP to evolve to an all-IP system in its core networks. Within 3GPP,

this initiative is referred to as Systems Architecture Evolution (SAE) also called Evolved Packet System (EPS). It provides more flexible service provisioning in addition to simplified interworking with 3GPP and non-3GPP mobile networks.

3.2 LTE Network Architecture

The LTE network architecture is characterized by the absence of a circuit-switched domain and a generally simplified access network. It features a non-hierarchical (distributed) structure for increased scalability and efficiency, and a model optimized to support real-time IP-based services. The LTE network comprises of new network elements compared to previous standards. As shown in Figure 2, LTE architecture can be broken down into three major sub-sections:

- Air Interface (OFDMA)
- RAN (E-UTRAN)
- Core Network (Enhanced Packet Core (EPC)

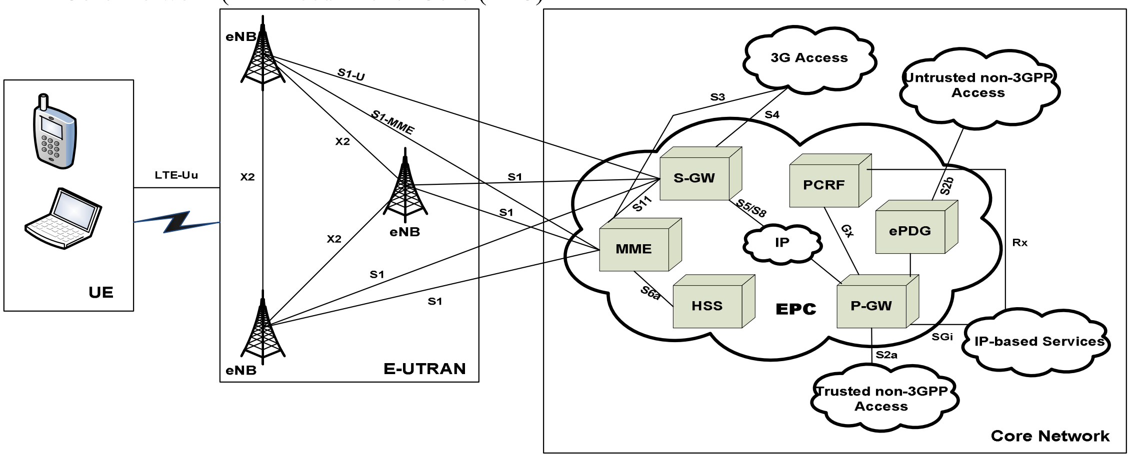

Fig. 2: LTE Network Architecture

3.2.1 Air Interface

At the air interface is LTE physical layer (PHY) which provides a highly efficient means of transmitting both data and control information between an evolved base station (eNB or eNodeB) and the mobile user equipment (UE) (Motorola Inc, 2007).

The LTE PHY as an advancement in cellular technology applications employs some advanced technologies such as Orthogonal Frequency Division Multiplexing (OFDM) and Multiple Input Multiple Output (MIMO) data transmission. The LTE PHY also uses Orthogonal Frequency Division Multiple Access (OFDMA) on the downlink (DL) and Single Carrier – Frequency Division Multiple Access (SC-FDMA) on the uplink (UL).

OFDMA is the multiplexing scheme in LTE DL. In the operation of OFDMA, data is directed on a subcarrier-by-subcarrier basis for a specified number of symbol periods, to and fro multiple users. This technology makes room for the efficient use of spectrum, very high peak data rates and also adds to the reduced latency. OFDM implementation in LTE is majorly due to its resilience to interference, multipath and spread. It supports scalable bandwidth, and the greater the bandwidth, the greater the channel capacity (Ian, 2012).

In the UL, a variation of OFDMA called SC-FDMA is used. SC-FDMA combines the low peak to average ratio offered by single-carrier systems with the multipath interference resilience and flexible subcarrier frequency allocation that OFDM provides, to support minimal battery requirement from the UE.

OFDM technology implementation in LTE also supports the incorporation of multiple antenna techniques such as MIMO. In previous telecommunications systems, the problem of reflections leads to multiple signals being generated. Using MIMO, these additional paths created by the signal are used to an advantage, such that, the same sent signal undergoes different channels, where the chances that all the channel conditions are bad is minimal. The benefits of this multiple antenna techniques are: reduced power consumption, higher capacity and throughput, improved spectral efficiency, higher range/wider coverage, lower interference and a better overall signal quality (Award Solutions Inc, 2009).

3.2.2 Radio Access Network (RAN)

E-UTRAN is the technology implemented in the access network of LTE. It consists of a network of fully interconnected eNBs as shown in Figure 2. This architecture implements no Radio Network Controller (RNC) as in 3G UTRAN; hence the E-UTRAN architecture is said to be flat or distributed (Award Solutions Inc, 2009). In LTE, the functionalities of the RNC rest on the eNB. This kind of architecture is simplified with a reduced number of nodes and interfaces leading to reduced Opex and Capex and also reduced latency and increased efficiency.

The eNBs are normally interconnected with each other by means of an interface known as X2 and to the EPC using the S1 interface. eNBs have the ability to communicate with multiple gateways for load sharing and redundancy.

The functions of the eNBs include (Alcatel, 2009):

- Radio Resource Management (RRM): This involves functions such as radio bearer control, radio mobility control, radio admission control scheduling and dynamic allocation of resources to UEs in both UL and DL.
- IP Header Compression: This ensures efficient use of the radio interface by compressing the IP packet headers that could cause unwanted overheads, especially for packets such as VoIP.
- Security: All information sent over the radio interface is encrypted.
- Connectivity to the EPC: This supports interfaces that handle signaling toward elements of the EPC which include: Mobility Management Entity (MME) and the bearer path toward the Serving Gateway (S-GW).

3.2.3 Core Network (CN)

The core network (CN) of LTE is called Enhanced Packet Core (EPC) as depicted in Figure 2, which represents a flat all-IP system designed to provide: much higher packet data rates, significantly low delay/latency; the capability of optimizing packet traffic within several kinds of operational circumstances having to do with bandwidth rationing and charging schemes; greater system capacity and performance; and a precise support for multiple RATs in the interests of seamless mobility. The EPC together with the E-UTRAN radio access method of LTE make up the Enhanced Packet System (EPS) which defines the state-of-the-art System Architecture Evolution (SAE). This is a 3GPP technical study item that defines the EPC and other elements (Gerhard, 2008).

The EPC is different from previous existing packet CNs in that it incorporates new entities such as the Mobility Management Entity, Serving Gateway and the Packet Data Network Gateway. The functions of the entities in the EPC are outlined below.

- Mobility Management Entity (MME): As opposed to 3GPP R4 where the Mobile Switching Centre (MSC) handles control distribution and bearer data, LTE separates control from bearer functions in the design of the EPC (Tektronix Communications, 2012) into the MME and S-GW.
- Serving Gateway (S-GW): The S-GW routes data packets between the P-GW and the E-UTRAN.
- Packet Data Network Gateway (P-GW): The P-GW acts as a default router for the UE. It is responsible for anchoring the user plane for mobility between some 3GPP access systems and all non-3GPP access systems. It is responsible for the allocation of IP addresses to the UEs.
- Home Subscriber Server (HSS): The HSS is the master data base used for storing subscription-related information in order to support call control and session management entities.
- Evolved Packet Data Gateway (ePDG): The ePDG provides capabilities for interworking with untrusted non-3GPP IP access systems. The ePDG provides security for the untrusted access by having a secured tunnel between the UE and the ePDG. It can also function as a local mobility anchor within untrusted non-3GPP access networks. In ePDG, lawful interception is crucial as untrusted access is involved.
- Policy and Charging Control Function (PCRF): PCRF is the only point of policy-based QoS regulation within the network. It is responsible for framing policy rules from the technical details of Service Date Flows (SDF) that will apply to the users' services, and then forwarding these rules to the P-GW for enforcement.

The LTE network entities as described above all interwork and interconnect with each other using several interfaces (Tektronix Communications, 2012) known as Reference points described in Table 1 below.

Table 1: Reference points in the LTE Network Architecture

Reference Points	Description
X2	This is the interface that connects the eNBs together.
S1-MME	This is the control plane protocol between the eNBs and the MME
S1-U	This interface connects the eNBs to the S-GW. It supports EPS bearer user plane tunneling and inter-eNB path switching during handover.
LTE-Uu	This connects the radio interface (i.e. eNBs) to the UE.
S11	This is the reference point between the MME and the S-GW
S2a	This the reference point between the P-GW and any trusted access network that accommodates a user in the interests of seamless mobility.
S2b	This interface accommodates a user's packets between the P-GW and an untrusted access network.
S3	It is the interface between the SGSN of 3G packet-core networks and the MME enabling user and bearer information exchanges for inter-3GPP access system mobility.
S4	It is the interface between the SGSN in a GPRS core network & the S-GW.
S5	It is the reference point between the S-GW and the P-GW. It supports mobility when the mobile moves out of the scope of the S-GW.
S6a	This is the reference point between the MME and the HSS.
S8	It is the reference point between the S-GW and the P-GW and it is used when the P-GW is in a different network (i.e. roaming).
SGi	This is the reference point between the P-GW and the PDN housing the IP-based services.
Rx	This interface carries policy rules for the PCRF to the IP-based services.
Gx	This is the interface that carries policy rules for the PCRF to the P-GW.

4. VoIP on LTE

The wide-spread success of mobile broadband, characterized majorly by the advent of LTE into the market has resulted in many changes in both carrier and user operations. Mobile broadband introduces new revenue and business opportunities to operators. On the other hand, it challenges the operators' SMS and voice revenues as they represent more than 70% (Ericsson, 2012) of their global business. Therefore the need for development and implementation of techniques to take advantage of the mobile broadband opportunities while also maintaining and growing the revenue from traditional communication services with more advanced and inviting features became necessary.

The features of LTE places it at the fore front of such technological developments since it brings about reduced latencies and higher capacities, resulting in an enhanced user experience for different kinds of services. LTE was seen as a completely IP cellular system just for carrying data as a voice format was not defined in the specification which represents a major omission for the system. As a result, telecom operators were pushed to come up with a global voice and messaging solution for LTE, and in general, developing a communication service model that can be evolved to support rich multimedia as demanded by users.

In order to carry voice and SMS traffic over the LTE network, associations were set up and options for providing this service were developed. These options are discussed below:

4.1 Circuit Switched Fall-back (CSFB)

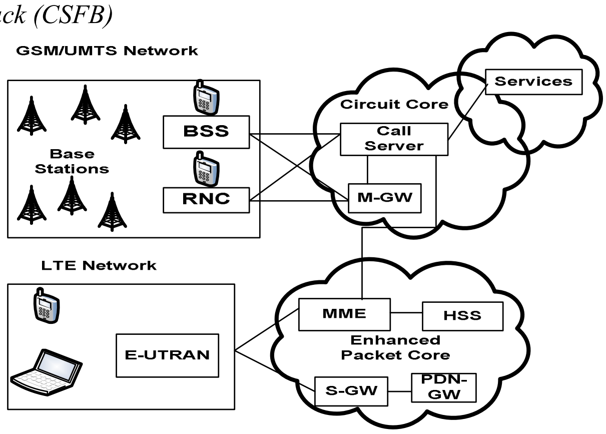

Fig. 3: Network Implementation of CSFB

CSFB is the standard developed by 3GPP under specification 23.272 as a voice-support solution for the early LTE deployment stages. It incorporates a 2G/3G network as shown in Figure 3. In CSFB, several processes and network elements enable the network to fall back to a 2G/3G circuit-switched connection before a voice call is initiated. This solution was recommended by the Next Generation Mobile Networks (NGMN) Alliance as a minimum roaming prerequisite for LTE terminal dealers and LTE operators that provide a CS voice service over GSM/WCDMA. CSFB also allows for SMS transmission as it is essential for several set-up procedures for cellular telecommunications. To enable SMS transmission, the mobile device uses an interface known as SGs (MME-MSC interface) which allows messages to be conveyed over an LTE channel. CSFB also demands support and modification of network entities, most especially the MSCs. MSC modifications are also necessary for the SMS over SGs facilities. The capacity of the MSCs and RANs overlaying LTE coverage must be sufficient to accommodate the increased traffic load from the LTE network. A disadvantage of CSFB is that, on fall back to UMTS and GSM with DTM (dual transfer mode) it supports concurrent voice and data, but does not provide this support when handing down to a GSM network without DTM, instead the packet switching session is suspended (Alcatel, 2009).

4.2 Simultaneous Voice - LTE (SV-LTE)

SV-LTE allows operators to support transmission of packet-switched LTE data services simultaneously with a circuit-switched voice service. The SV-LTE option provides the facilities of CSFB as well as running a packet-switched data service both at the same time. However, it requires two radios (one for voice and one for data) to run simultaneously on the handset resulting in more processing capabilities for the handset, which brings about a significant degradation impact on battery life.

4.3 Over-the-top (OTT) VoIP

OTT VoIP solutions can be described by applications such as Skype and Google Talk. This method influenced the widespread development and deployment of VoIP and has advanced to the point of being pre-installed in high-end/smart phones. However, due to the lack of a handover scheme for service transfer to a circuit-switched domain, OTT solutions cannot provide a satisfactory user experience in the absence of LTE coverage; therefore, the adoption of this solution by OTT clients will depend on mobile broadband coverage. OTT VoIP service providers do not have control over QoS in the wireless network, therefore, cannot ensure a good quality of experience (QoE) under all load situations (Martin, 2009).

4.4 Voice over LTE via Generic Access (VoLGA)

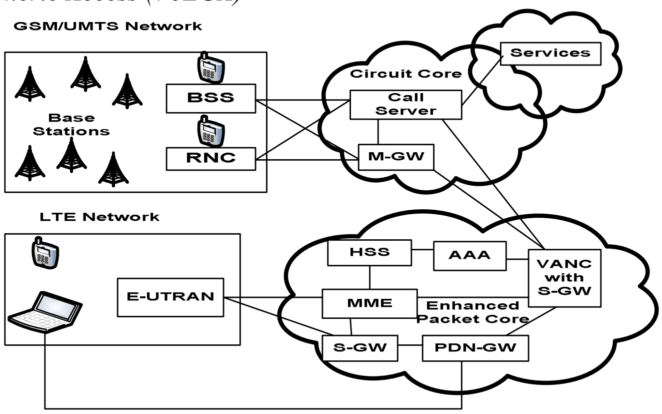

Fig. 4: Network Implementation of VoLGA

VoLGA, specified by the VoLGA Forum, is also a voice-support solution for the early LTE deployment stages. VoLGA operating principles as shown in Figure 4, relies on the existing 3GPP Generic Access Network (GAN) standard adding Wi-Fi as an access technology to 2G/3G 3GPP networks. The aim of GAN is to extend mobile services over a generic IP access network as demonstrated by Wi-Fi-enabled phones. With GAN-operated dual-mode mobile phones, all services are available over either the normal 2G/3G networks, or over Wi-Fi hotspots while enabling seamless/transparent mobility between the two networks.

The requirements of GAN include: dual-mode mobile devices which have both a GSM/UMTS radio interface and a Wi-Fi radio interface. When these dual-mode devices detect the availability of a safe/appropriate Wi-Fi network, they connect to the Wi-Fi access point and register with the GSM/UMTS CN over the Wi-Fi link and the Internet. A GAN gateway provides a secure connection from the subscriber to the network operator's infrastructure for the conveying of voice calls and other circuit-switched services such as SMS between the mobile device and the Gateway over the intermediate Wi-Fi link and Internet access network. VoLGA applies this principle by replacing the Wi-Fi access with LTE.

From the circuit-switched network point of view, VoLGA requires just software improvements on the circuit-to-packet gateways which is already a feature in GAN. As opposed to CSFB, no modifications are required on the MSCs or the LTE CN and RAN endpoints. This serves as an advantage in multi-vendor MSC network, giving opportunity for rapid development and market introduction. VoLGA enables the utilization of all other circuit-

switched services such as SMS (which is a very important necessity) over LTE without any modifications in the network.
With respect to the LTE network, the only new network element introduced is the VoLGA Access Network Controller (VANC) which connects to the P-GW (or PDN-GW) via the SGi interface through which signaling and user data traffic are transported. The VANC was introduced to interwork the LTE and GSM/UMTS networks. VANC is introduced in-between the EPS and MSC, and it provides an LTE overlay access pipe for transparent forwarding of IP packets from the terminal to the MSC.
On the mobile device side, the protocol stack developed for GAN can be applied since both Wi-Fi network and LTE are IP-based. The only difference is in the addition of software to include the LTE access technology as a radio bearer and also a modified handover procedure to allow a smooth handover of current voice calls to GSM/UMTS when the subscriber leaves the LTE coverage area.
VoLGA supports smooth global LTE roaming. If VoLGA is supported by the visited network, all services can be delivered via its circuit to packet gateway and the MSCs in the visited network. Asides the benefits the user experiences, the network operator also enjoys benefits in that it allows delivery of important services such as compulsory information on roaming charges via SMS while roaming (Martin, 2009). To permit handovers from the LTE network to GSM/UMTS, both the E-UTRAN and the MME must support Single Radio Voice Call Continuity (SRVCC) according to 3GPP TS 23.216. Support of the Sv interface to the VANC must also be enabled.
The adoption of VoLGA is at a disadvantage as its standards have not been accepted by 3GPP, neither is there any guarantee of eventual acceptance.

4.5 One Voice Initiative (known as VoLTE)

The VoLTE method of providing voice service over an LTE network makes use of 3GPPs IMS (IP Multimedia Subsystem) Multimedia Telephony (MMTel) standard for LTE's voice service delivery in TS 23.228, enabling it become part of a rich multimedia solution. The features of IMS includes: voice services provisioning such as fundamental voice origination/termination, calling line identification, and supplementary services, as well as value-added, advanced multimedia services such as video sharing by supporting media additions and subtractions at any time during a call. It is seen as a long-term solution. The One Voice alliance of over forty network operators and manufacturers published their 3GPP-compliant Voice over IMS profile recommendations in November 2009 and then on 15th February, 2010, at the 2010 Global System for Mobile Communications Association (GSMA) Mobile World Congress. GSMA announced that they were supporting the One Voice solution to lead the global mobile industry towards a standard way of offering voice and messaging services for LTE. This VoLTE method eradicates the need for 2G/3G voice and the challenges of multiple networks (circuit and packet) and additional components and cost in devices by transmitting the voice over the LTE network using Adaptive Multi-Rate (AMR) coding. In development/deployment of this technology, three interfaces are defined:

- The User Network Interface (UNI): This is the interface between the user's equipment and the operator's network.
- The Roaming Network Network Interface (R-NNI): This is the interface between the Home and Visited Network, used by customers who are not attached to their Home networks e.g. in a roaming situation.
- The Interconnect Network Network Interface (I-NNI): This is the interface between the networks of the two parties making a call.

The handover schemes of VoLTE are: Dual Radio Voice Call Continuity (DRVCC) for user equipment that have and support 3G and LTE radios enabling a seamless handover in spotty coverage, Single Radio Voice Call Continuity (SRVCC) which enables seamless handover for spotty coverage for devices with a single radio (i.e. either 3G or LTE at a time) (Zahid, 2012).

4.5.1 Voice and SMS over IMS Architecture

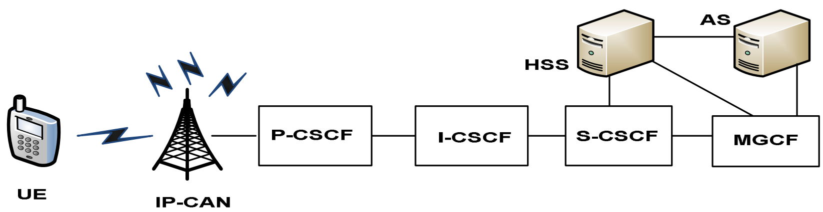

Fig. 5: A Section of the IMS Network Architecture

The IP Connectivity Access Network (IP-CAN): It provides IP connectivity and mobility. It serves as the intermediary through which the IMS terminal sends control plane signaling and media transfer to the IMS core network. In LTE, the IP-CAN is made of the EPC and the E-UTRAN (Gessner, 2011).
The Call Session Control Functions (CSCF): It consists of the core components of an IMS network as shown in Figure 5 and there are three of them:

- Proxy-CSCF (P-CSCF): The P-CSCF is the initial point of contact for a user. It behaves like a proxy, in that, it collects requests and forwards them.
- Interrogating-CSCF (I-CSCF): This serves as the entry contact within the operator's network for all connections to the subscriber.
- Serving-CSCF (S-CSCF): The features of the S-CSCF are to: handle the registration process, determine routing decisions, sustain sessions, and download of user information and service profiles from the HSS.

The Home Subscriber Server (HSS): This is the user's master database. It can be compared to the Home Location Register (HLR) in GSM mobile radio network. It contains the user subscription information that the network entities require for session handling.

Application Server (AS) makes specific IP applications available like messaging.

Media Gateway Control Function (MGCF): This entity works hand-in-hand with the SIP signaling. It manages the circulation of sessions across multiple media gateways.

The IMS architecture highlighting the different CSCF entities makes sense when roaming is in consideration. Network providers/operators are unwilling to divulge their internal network structure and are also against access to their user databases. Meanwhile, a UE always communicates with the local P-CSCF in the accessed network, this P-CSCF must be denied access to the HSS. The I-CSCF makes the network architecture invisible to other network operators.

IMS uses a set of internet-based protocols such as: SIP, Session Description Protocol (SDP), RTP and RTCP, Extensible Mark-up Language (XML) Configuration Access Protocol (XCAP) and the Dynamic Host Configuration Protocol (DHCP).

4.5.2 Network Implementation of VoIMS on LTE

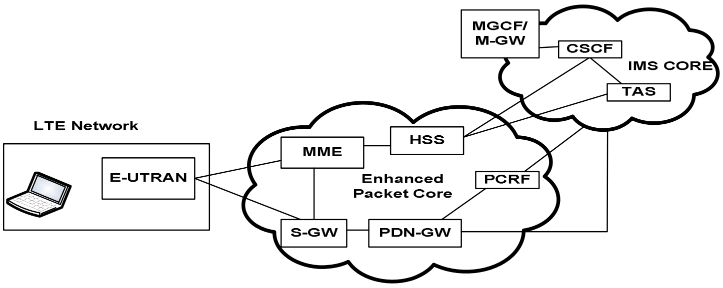

Fig. 6: Network Implementation of VoIMS

The network implementation of VoIMS (Voice over IMS architecture) as shown in Figure 6, requires the deployment of the IMS core comprising of: CSCF, Telephony Application Server (TAS), and other components necessary for the proposed services to be rendered. VoIMS terminals are also required to provide support to the IMS mobile client. For SMS support, an IP-SM-GW (IP Short Message Gateway) is required as well as an upgrade to the HSS to support the presence of the new IP-SM-GW in the network.

The One Voice option of transferring voice over an LTE network using IMS has been accepted globally as the end-goal solution in providing this service. This method enables the LTE/IMS network to be fully utilized yielding significant OpEx savings on using a flat, all-IP network. It provides conversational services and gives opportunity for network operators to come up with new revenue sources, advanced voice and data services. In addition, service providers are capable of offering converged fixed and mobile services on their wired and wireless networks using voice over IMS.

4.5.3 Benefits of VoIP Implementation on LTE

As VoIP is implemented on an LTE network, it takes advantage of the benefits of LTE as an access technology making it an irresistible technology most especially using the IMS-based platform. Below are some of the benefits of this VoIP implementation on LTE

1. Larger capacity and coverage to support full multimedia services and fixed mobile convergence scenarios.
2. Support for wider range of services.
3. Evolution to an all-IP network with fewer nodes leading to reduced latency.
4. In favour of the users, VoLTE discharges the heavy duties of voice communication (such as echo cancellations and removal of background noise) to the RAN thereby preserving the battery life of the communication device.

4.5.4 Benefits of Voice over LTE network using IMS are:

1. It conserves the bandwidth of LTE during voice calls such that the data services still retains the LTE bandwidth while minimizing call setup delay.
2. It assures global interoperability and roaming.
3. It has the capability of generating the largest possible ecosystem in which supply of handset and multi-

vendor interworking are affected.
4. It provides an all-IP network giving room for OpEx savings.

5. Performance Comparison of Voice Options on LTE Networks

The Table 2 gives a summary and comparison of all the voice options for LTE networks.

Table 2: Performance comparison of the options for providing voice services on LTE network

	CSFB	SV-LTE	OTT	VoLGA	VoLTE
Mode of Voice Service	CS	CS	PS	CS/ PS	PS
Network providing radio access	GSM/UMTS	GSM/UMTS	LTE	GSM/UMTS or LTE	LTE
Quality of voice call setup	Some delay	Some delay	Fast	Fast	Fastest
QoS Assurance	GSM/UMTS	GSM/UMTS	LTE-based	Dependent on current radio access.	LTE-based
Support for simultaneous Voice and Data	GSM – No UMTS – Yes	CS GSM/ UMTS - Voice LTE - Data	Yes	Yes	Yes
Support for advanced services	No	No	No	No	Yes
Flat, all-IP architecture	No	No	Yes	Partial	Yes

6. Conclusion

Even with the increasing demand for data services, voice services still yields a higher revenue percentage for the network service providers as the necessity for voice communication and its value cannot be undermined. Therefore, users continually seek cheaper means of making voice calls which was made even easier with the advent of VoIP service by OTT players such as Skype.

Network Service Providers (NSPs) have sought means of protecting this voice revenue by offering VoIP services as well. But these services demand minimum service guarantees that require more than the Best Effort (BE) structure of today's IP networks can offer. Real-time audio and video services also places a demand on bandwidth which significantly exceeds the capacity supported by current 3G cellular and WLAN technologies. But with the recent developments in wireless broadband access technologies among which LTE evolved, one can say there is a green light at the end of the tunnel.

In this paper, the survey of VoIP options on LTE network and their comparison have shown that the option of VoIP on LTE which incorporates IMS architecture is the best method of implementation. This method leverages on the benefits of the IMS architecture and functionalities. It provides an opportunity for advanced services support. It eliminates the need for any circuit switched fall-backs making the system a full IP network.

As NSPs take advantage of the capabilities of LTE, it will result in positive rapid changes in mode of communications. Consumers are also not left out as they are set to experience previous and upcoming communications services in "high definition (HD)".

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