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Trends in the Evolution of Voice Services: A Comprehensive Survey

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Abstract Mobile network operators are increasingly striving to substitute legacy telecommunication technologies in their networks with the contemporary ones. Modern, future-proof architecture that provides better service quality, requires easier and cheaper maintenance, and consequently brings greater financial benefits is the main driving force for that action. In this moment, Long Term Evolution (LTE) deployment is a goal most mobile network operators are aspiring to. This paper describes presently ongoing changes in the mobile communication networks from the perspective of voice services they provide. Namely, LTE network is, so far, mainly recognized as a "data oriented" network. Having in mind enormous mobile data traffic increase, deployment of that kind of network is fully understandable and justified. However, voice services are still important part of telecommunications' market offer. So, the above mentioned changes are leading not only toward satisfaction of growing needs regarding mobile data traffic, but also toward utilization of LTE network attributes for the purposes of voice communication. Complete transformation of mobile networks architecture and evolution of traditional voice communication will occur in the process. So far, that evolution has resulted with development of a mechanism know as voice over LTE. However, the mentioned changes are coming gradually and will take a certain time to be fully accomplished. In the meantime, some transition solutions are defined and deployed, in order to enable uninterrupted provisioning of voice services. Their description is included in the paper as well. At the end, relevant forecasts of several network parameters have been discussed.

Keywords LTE · VoLTE · IMS · CSFB · SRVCC

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1 Introduction

Long Term Evolution (LTE) presents outcome of a natural developing process of its predecessors—Global System for Mobile Communications (GSM) and universal Mobile Telecommunications System (UMTS) network technologies. It is developed by the telecommunications standard development organization—3rd Generation Partnership Project (3GPP) and described in their Release 8 [1]. The first commercial launch of LTE network happened in summer of 2011 in Canada, although the first LTE service where launched earlier, at the end of the 2009 in Scandinavia.

Ongoing rapid expansion of LTE networks deployment is fueled by tremendous increase in mobile data usage. Namely, Cisco forecasts [2], have predicted growth of 61% in mobile data traffic in period from 2013 to 2018. That growth can be explained by high penetration of smartphones, tablets and other mobile data devices that support data intensive applications such as mobile games, mobile videos and location based services. In order to support constantly increasing data traffic, mobile network operators have speed up LTE deployment in their networks.

Network enhancements that characterize LTE, in comparison to legacy networks, provide larger bandwidth over a simple, flat Internet Protocol (IP) architecture and quality of service (QoS) [3], for the delivery of already mentioned data intensive applications. They have resulted with wireless communication of high-speed data via mobile phones and data devices. Additionally, LTE delivers spectral efficiency, higher throughput, lower latency and improved user experience. Because all of that, LTE is commonly referred as Evolved Packet System (ePS). It unifies Evolved UMTS Terrestrial Radio Access Network (E-UTRAN) and Evolved Packet Core (EPC).

Aldo LTE seems to be perfect answer for the mobile data traffic challenge, it brings back the old issue on the table. Namely, LTE supports all IP based communication but lacks traditional support for Circuit Switched (CS) communication. This fact is reintroducing the long forgotten problem of voice services providing and represents the first challenge for the mobile network operators.

The second challenge comes in the form of Over-The-Top (OTT) concept, preceded by the appearance and wide distribution of smartphones in combination with "data oriented" network such as LTE (even 3G). OTT concept refers to the variety of services (mainly texting, voice and video) subscribers use over the network services of their network provider. Hence, OTT provider can be defined as a service provider that offers telecommunication services through Internet, but neither owns a telecommunication network nor leases networking infrastructure from another network operator. Simply, OTT providers treat the network providers as the network carriers that only carry IP packets from source to destination.

In order to overcome technology challenge from one side, and commercial/market challenge from the other side, mobile network operators should be able to provide solution that will deliver superior grade of services and that will outperform OTT providers' "best-effort" service.

The paper is organized as follows. After the Introduction, Sect. 2 presents currently deployed solution for voice communication in contemporary networks, where, in most cases, legacy technologies are combined with LTE. VoLTE logical architecture is explained in Sect. 3, along with simplified representation of VoLTE to VoLTE call/session. Section 4 describes the concept of Single Radio Voice Call Continuity (SRVCC) and its relevance in contemporary networks. Benefits and challenges of VoLTE concept are discussed in Sect. 5. Finally, paper is concluded in Sect. 6.

2 Currently Deployed Solution for Voice Services in Mobile Networks

From the subscribers' point of view above elaboration might be a bit confusing. Namely, according to Groupe Speciale Mobile Association (GSMA) research [4], at the end of January 2015, there were 352 operators with commercially deployed LTE networks. So, LTE is deployed in more than half of the world's mobile markets (124) [4], and this number is expected to almost double by 2020. Yet, LTE does not support traditional voice communication. On the other hand, subscribers are using voice calls (as well as other CS services) by mobile devices without any problems. This is provided by a concept known as CS Fall Back (CSFB) [5], which is often referred to as the first phase of voice evolution for mobile LTE devices.

CSFB supports voice services for LTE users by reusing GSM/UMTS network. Mobile devices, normally attached on LTE network for data services, are forced to fall back to the legacy network (3G or 2G) when subscribers want to use CS services. Hence, end users will get CS services with QoS to which they are accustomed. In this way, life of the GSM/UMTS networks is extended. That fact is very useful from the perspective of mobile network operators, because substitution of legacy mobile networks with LTE is the process that takes a certain amount of time and cannot be performed instantly. GSM/UMTS components are all reused in CSFB (no new network elements need to be added) with minor upgrades. User equipment (UE) also reuses GSM/UMTS client with only a few added enhancements for CSFB.

Aldo it appears that CSFB is a good solution, it is better to be considered only as a temporary one. The additional steps in switching from LTE to legacy networks for voice calls, expectably, introduce an extension of call setup time duration. Intensive signaling is causing that CSFB may take up to 500 ms to complete. In addition, call setup duration may be increased if UE conducts measurements in order to find a suitable GSM/UMTS cell to use, prior the standard location update (necessary for originating or answering a call). Overall delay may be enough to be noticed by some LTE subscribers. Hence, CSFB is good enough to serve till the final solution is developed and deployed.

3 Logical Architecture of VoLTE Concept

A standardized, future-proof solution of previously described issue is VoLTE concept [6–8]. VoLTE ensures delivery of CS services over LTE, relying in that process on IP Multimedia Subsystem (IMS) core network. Initial specification of IMS has begun in 3GPP Release 5 [1], and was refined by subsequent Releases 6 and 7 [1]. It is expected that VoLTE will take over complete mobile voice traffic in years to come. In addition, VoLTE will prepare mobile networks for easier transfer to fifth generation (5G) of network technologies whose standardization and definition is still in progress [9, 10].

VoLTE logical architecture consists out of: VoLTE UE, E-UTRAN, EPC, and already mentioned IMS core network. Each of those elements is essential for establishing successful VoLTE call/session and has dedicated role in the process.

VoLTE UE contains functionality to access LTE Radio Access Network (RAN) and EPC and hence to allow mobile connectivity. In order to enable access to VoLTE services, UE has embedded IMS stack and VoLTE IMS application.

E-UTRAN is RAN standard that is optimized for packet data. It consists of a single node—eNode B, that interfaces with UE.

EPC is the latest evolution of 3GPP core network architecture. Namely, in legacy telecommunication technologies circuit-switching and packet-switching have represented dual domain concept that was used on the core network side. By introducing 4G technology, IP was chosen for the key transport protocol for all services. Hence, CS domain is not needed any more and PS domain had to be enhanced to support all existing traffic (voice and data). That enhancement resulted with development of EPC.

IMS is an open-system, access independent network architecture that delivers services to mobile users based upon two main IP protocols standardized for signaling and session establishment. These IP protocols are Diameter [11], and Session Initiation Protocol (SIP) [12]. Diameter is dedicated for subscriber services such as authentication, authorization, accounting, mobility, policy, charging, etc. On the other side, SIP represents a signaling mechanism which controls all traffic in the network and is used to establish voice, video, and messaging sessions between participants.

Besides significant role in VoLTE mechanism, IMS is capable to provide fixed IP telephony service, as well as full fixed-mobile convergence. Many network operators have already used this possibility, in order to offer complete telco service to their end users from one side, and to test and verify IMS architecture functioning for future tasks from other side.

IMS architecture can be parsed in three layers: transport, application and control layer. The transport layer is the entry/exit point for IMS network and includes any kind of access network (fixed, mobile, wireless). The control layer is in charge of providing call session and call session control. A central entity of the control layer is Call Session Control Function (CSCF). Session Border Controller (SBC) is usually inserted into the signaling and/or media paths between IMS terminal and control layer (CSCF) from variety of reasons (security, connectivity, regulatory, QoS,…). The application layer comprises application servers (AS), that host and execute services for the subscribers and communicates with CSCF using SIP.

Simplified voice call/session scheme between two VoLTE users is presented in Fig. 1. As it can be seen, both users (originating A and terminating B) have to be connected to LTE network that supports VoLTE, while signaling and media (bearer) are using EPC and IMS infrastructure that leans on IP backbone. In case one or both users came out of LTE coverage during VoLTE call/session, it might be assumed that voice communication between them will be dropped. However, a mechanism that successfully overcomes this situation and provides call/session continuity has been developed and will be explained in Sect. 4.

4 Providing of Voice Call Continuity

In countries where it is deployed, LTE currently coexists with legacy mobile networks (2G and 3G), and that will be the case for a significant period of time. Having in mind that legacy networks do not support voice over IP (VoIP), VoLTE call/session on the device moving out of LTE coverage will be dropped. Hence, voice handover to legacy CS systems is a key capability that has to be supported until LTE fully substitute legacy networks and completely take over their coverage.

The main challenge in this kind of hybrid network environment is transfer of VoLTE calls/sessions in progress to legacy 2G/3G CS voice calls while retaining established QoS.

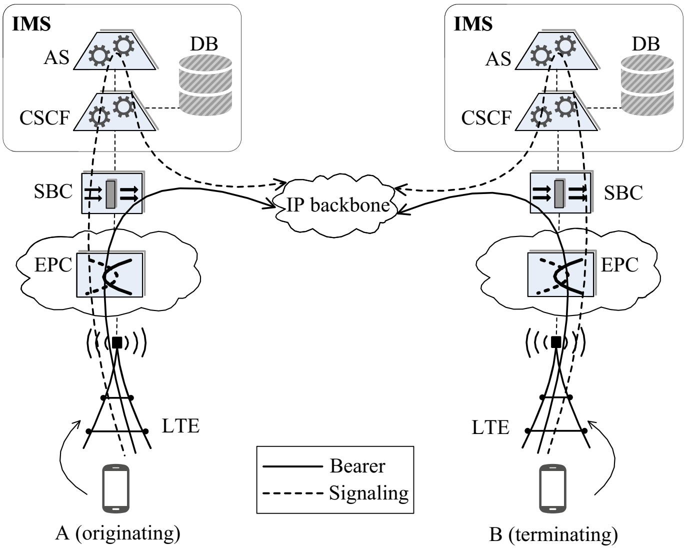

Fig. 1 Simplified representation of VoLTE to VoLTE call/session. DB represents the data base that stores subscriber-related data

This specially refers to emergency calls, because their continuity and QoS has higher priority and in many countries presents strict regulatory requirement.

The concept called Single Radio Voice Call Continuity (SRVCC) [13], is defined in order to meet described requirements. The solution lies in using a single radio in UE combined with adjusted supporting network infrastructure.

During the handover of VoLTE call/session to legacy CS system, SRVCC mechanism provides full network control of the call, while subscriber maintain access to all his services implemented in IMS AS.

The handover process is accomplished in two steps:

1. The inter-radio access technology (IRAT) handover of UE from LTE radio access to UMTS/GSM radio access.
2. The session transfer that moves access control and voice media anchoring from EPC to legacy CS core.

Session transfer request to IMS AS represents initiation of the handover process. IMS AS responds simultaneously with two commands: one to LTE network and one to 2G/3G network. LTE network (that handles subscriber's voice call in progress) receives an IRAT handover execution command through EPC and LTE RAN. In this way, subscriber's UE is instructed to prepare to move to CS network for the voice call. CS network (where the user's voice call is being sent) receives session transfer response, preparing it to accept the call in progress. With acknowledgements that commands have been executed, UE and IMS AS switch to CS network to continue the call. Hence, continuity of the voice call is retained and subscriber is not aware of any change.

5 Benefits and Challenges of VoLTE Concept

Extensive analysis [14–19], have been conducted in previous period, in order to give proper and complete information to mobile network operators, telecommunication vendors and end users regarding characteristics of VoLTE mechanism. Having in mind wide scope and complexity of network architectural changes VoLTE brings, right justification for its' introduction had to be given.

Among the others, extensive research was conducted by Signal Research Group (SRG) from June to July 2014 [14], in order to evaluate performance of VoLTE. Comparisons are made among services provided by VoLTE, by 3G technology, and by OTT providers. Results that are achieved undoubtedly go in favor of VoLTE. In this Section, summation of analysis results obtained from several sources [14–19], will be briefly presented, so that benefits of VoLTE concept can be clearly visible.

The analysis of SRG [14], found that VoLTE call/session quality greatly exceeds the quality of 3G voice, and also is significantly better than HD voice service offered by OTT providers. When it comes to call setup time, VoLTE call/session setup time is nearly twice as fast as 3G CSFB call setup. In case of leaving LTE coverage, SRVCC mechanism is triggered, and VoLTE calls/sessions are successfully handed over to 3G network.

VoLTE especially outperforms OTT applications in case of background applications running on UE and transferring data with the network during the call. Namely, there is no indication that these actions impact VoLTE call/session in any way, while delivering of OTT service in these circumstances is seriously jeopardized. In addition, VoLTE really shows its' domination when it comes to network requirements since it is consuming them far less than OTT voice call. This directly implies longer estimated device battery life of UE and more efficient network for the mobile network operator.

Especially convenient for end users is the fact that, compared to OTT applications, VoLTE users can use phone's standard dialer and contacts when making calls (as well as when using other CS services), and there is no need for any kind of additional application.

It is important to note at the end that VoLTE enables service providers to reuse spectrum occupied by legacy technologies for LTE network, and hence to deliver a superior service and even more enhanced end user experiences.

When it comes to challenges that go along with VoLTE, increase of signaling load on the control plane may be treated as a key one. In addition, non-voice application services such as online games or streaming video make that signaling load increases further.

According to the latest Oracle Communications report from October 2015 [17], Diameter traffic will increase from 30 million messages per second (MPS) in 2014 to more than 395 MPS in 2019. This is more than tenfold increase of signaling load, and represents a compound annual growth rate (CAGR) of 68%.

It is expected that over 2.5 billion of LTE connections (excluding machine-to-machine) will exist by 2020 [18]. According to ABI research [19], nearly 56% of LTE connections will be using VoLTE services by the end of 2019.

These forecasts are very important from the perspective of already mentioned signaling load increase. Namely, number of Diameter messages that are exchanged is directly dependent from the number of LTE subscribers on the network and from the number of applications running on their UE. Moreover, in comparison with a simple data session for connection to the Internet, VoLTE session creates more than double the amount of Diameter signaling. It is expected that, due to VoLTE alone, Diameter Signaling rise at 49% annual growth rate through 2019 [17].

SIP signaling load has rising trend as well. Except mentioned growth of LTE connections number, increase of SIP signaling load is caused by couple more reasons. Namely, CS access and interconnections are being substituted by PS access. Also, SIP trunk usage is rising at the rate of about 35% a year [17].

Having in mind previous elaboration, mobile network providers need to carefully design their networks so that anticipated increase in traffic and in signaling can be processed in the proper way.

6 Conclusions

Evolution of technology, by default, brings the enhancement of existing systems, tools, services, etc. It means that their characteristics are improved, with newly deployed features and functionalities. However, that does not mean that some of the basic features and functionalities are lost in the process. That is exactly what happened with introduction of LTE. We have got the high speed data wireless communication over a simple, flat IP architecture from one side, and have lost the traditional CS capabilities from the other side. VoLTE concept has overcame all obstacles, and offered a way to provide exceptional quality for CS services.

However, not only mobile network operators are interested in providing of telecommunication services to end users. OTT providers have taken the opportunity to participate in this data era race as well.

OTT providers offer alternative methods for providing voice and other multimedia services over IP. They have developed plenty of easily accessible and affordable applications that enable exchange of all kind of multimedia content, by only using the Internet resources. Hence, logical question might be raised: why do we need VoLTE at all? Or, why should we pay it to the network providers? Here follows the most important reasons.

The analysis of SRG found that VoLTE users enjoy considerably better call quality, faster connectivity and substantially less drain on the batteries of their mobile devices. In addition, VoLTE enables LTE operators to simultaneously deliver both faster mobile broadband and IP based communications, including HD voice, HD video and messaging across any connected network, device and application. Hence, end users can extend their faster LTE data experience to voice calls or to connected devices, such as tablets and laptops so they may talk clearly in HD while browsing the Web, streaming movies, playing games and sharing multimedia content at LTE speeds. Also, LTE offers twice the spectral efficiency of 3G network technology, that makes possible for VoLTE to handle twice as many calls. In this way, VoLTE is helping to optimize the use of radio resources and reduce costs, that in overall means consuming less network resources.

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