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Cloud voice service as over-the-top solution for seamless voice call continuity in a heterogeneous network environment

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ABSTRACT

Despite the current introduction of the 4G mobile network technology Long Term Evolution (LTE) and the existing heterogeneous network infrastructure, hardly any service provider supports seamless cloud voice service owing to the high integration cost.

In order to address this challenging issue, we present a cost-effective Virtual Room based vertical handoff (VOOH) as an Over-the-top (OTT) solution, which is network provider independent and only uses existing wireless access technologies (e.g., LTE, 2G/3G, WiFi) for connectivity purposes. That means no changes in the underlying network technologies are required that result in lower integration effort. Besides providing handoff of ongoing Voice over IP (VoIP) calls seamlessly between WiFi and LTE, unlike related solutions (e.g., Circuit-Switched Fall Back (CSFB)) VOOH presents a cost-effective OTT solution to support voice call continuity between LTE and the circuit-switched channel of 2G/3G networks. In the long term, VOOH also enables data-offloading (e.g., via WiFi) to lower the traffic load of cellular base stations.

While our previous work has mainly focused on proof of concepts and experimental performance evaluations, this manuscript proposes a novel analytical and simulation model to analyze the scalability of the VOOH solution that is discussed for specific use case examples. Moreover, the impact of an enhanced VOOH (eVOOH) approach is presented to improve the system performance in terms of blocking probability. Based on the validated models, the results illustrate that eVOOH outperforms the original solution that is shown by lower call blocking probabilities.

1. Introduction

Nowadays mobile communication is characterized by the use of voice calls and Internet usage on the run. For example, users communicate during traveling, running and walking nearly 24 h a day. Therefore, mobility support allows seamless voice calls and Internet usage in cellular networks. But the restricted coverage and capacity of cellular networks is a big challenge. With the spread of mobile services and the evolution of smartphones, the development of hybrid heterogeneous networks, consisting of various network access technologies is a first solution to enhance capacity and coverage of cellular and other networks (e.g., WiFi).

We focus on the cross-technology handoff, for example between UMTS and Wifi, to enable seamless voice communication. Depending on the radio access network technology, hard and soft handoff take place, but transparently for our solution. As our solution uses two parallel connections, the handoff will be seamless. We intend to provide a resource efficient and mid-term solution for the use in hybrid heterogeneous infrastructures. The future of mobile applications will be packet-switched, but, especially in case of voice telephony, circuit-switched technologies will coexist until the old infrastructure can be renewed.

1.1. Motivation

With the ongoing introduction of next-generation networks (NGN) like the 4G mobile communication technology Long Term Evolution (LTE), the today's heterogeneous network environment (e.g., UMTS, LTE, WiFi) is continually growing. Despite the given existing infrastructure, hardly any service provider offers noninterruptible cloud voice service across these different networks due to high integration effort (Paisal, 2010a). Current providers like Siemens with their Open Scape cloud solution (Siemens Company, 2013), (NFON Project, 2013) or Genesys (Genesys Lab, 2013) only provide pure IP-based voice cloud services without handoff support, which do not fulfill nowadays mobile communication for seamless service provisioning. Although latest mobile phones enable VoIP and circuit-switched calls via different wireless interfaces, a service for

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seamless voice call continuity among heterogeneous networks is rarely deployed.

In terms of mobile telephony and besides the dominating circuit-switched calls, the popularity of VoIP will be additionally driven more by the 4G mobile technology. Unlike the 3G UMTS/HSPA (Prokkola et al., 2009), the latest network technologies present a promising option to improve the Quality of Service (QoS) mobile packet-switched calls. However, it is an open question whether network operators will support VoIP via 4G as mobile telephony in the future as well as whether LTE can reach at least similar QoS like for circuit-switched calls. Furthermore, it is presumed that VoIP via packet-switched and circuit-switched calls will coexist in the foreseeable future. Our work intends to support the evolution of the networks towards pure packet-switched technology also for voice. As long as circuit-switched telephony will be around, there is a potential and need for hybrid solutions (e.g., LTE CS-fallback).

Given this trend, service providers and network operators need a scalable and cost-effective cloud voice service as an Over-the-top (OTT) solution (Bertin et al., 2011) to benefit earlier from seamless voice call continuity. This network operator independent solution has the advantage that no changes are required in the underlying network layers. Only today's existing wireless access technologies are used for connectivity purposes to deliver the cloud voice service. Especially, the coverage of cloud voice calls can be enhanced by using seamlessly the present heterogeneous network infrastructure. Consequently, such an OTT service has more attracted as a resource optimizing and high-performance solution for private customers and business environments (Zhang et al., 2010).

1.2. State-of-the-art analysis

Seamless vertical handoff solutions can be divided into two groups: solutions that enable synchronous communication and solutions for asynchronous applications. All voice based applications have to be synchronized in contrast to most data based applications that are based on asynchronous communications.

There exist several solutions for asynchronous data based communication, such as MIPv6, SIP or mSCTP. Mobile IPv6 (Al-Helali et al., 2009; Devarapalli et al., 2005) is based on a home agent and requires modifications at both sides (client and server). The mobile stream transmission protocol (mSCTP) (Stewart et al., 2007; Riegel and Tuexen, 2007) needs a fitting TCP application since all TCP based applications have to be adapted to this solution. This results in a high integration effort. Currently, there is no widespread usage of MIPv6 and mSCTP by network providers.

Our objective is to provide a solution that is usable with low integration effort and can be used directly with smartphones. To support synchronous applications, a centralized solution is needed. Subsequently, we focus on seamless handoff between voice calls in this paper.

For seamless voice calls between circuit-switched 3G UMTS networks and unlicensed wireless networks, commercial network providers can benefit from the cost-intensive as well as resource-consuming UMA (Unlicensed Mobile Access) that requires UMA Network Controllers (UNC) as neighbors of GSM base system controllers (BSC) and specific UMA enabled mobile phones (Yarali and Saleeba, 2010).

Another related network operator dependent approach uses IMS (IP Multimedia Subsystem) as basis technology presenting a pure future IP-based infrastructure for communications (Kou et al., 2010; Bellavista et al., 2010; Dutta et al., 2007). In this case, the complex IMS architecture of the next-generation network (NGN) needs specific gateways to convert circuit-switched and VoIP calls. In Salsano et al. (2006a), the authors suggest a pure SIP mobility concept based on Session Border Controller (SBC) to enable seamless VoIP calls between the packet-switched channel of 3G UMTS and WiFi. This implies to integrate the SBC into the 3G core network, which is usually related to a high integration effort. Unlike SBC, our proposed Over-the-top VOOH service provides a cost-effective solution.

There are a lot of solutions in the literature on SIP based approaches for seamless voice calls like (Seta et al., 2007; Bellavista et al., 2006; Cardenete-Suriol, 2007) that support vertical handoffs between 3G/4G and unlicensed wireless networks. However, these solutions only consider pure VoIP handoffs between heterogeneous networks using the packet-switched channels. A vertical handoff between packet- and circuit-switched networks is not taken into account. Unlike SIP based approaches, our VOOH service provides a solution for heterogeneous network that is not entirely built on SIP.

For seamless roaming between VoIP via LTE and circuit-switched calls, Circuit Switched Fall Back (CSFB) describes a first solution that enables mobile phones to fall back to 2G/3G networks (3GPP TS, 2006). However, CSFB has longer call setup times resulting in degradation of user experiences and currently executes hard-handoff. In contrast to CSFB, VOOH enables seamless soft-handoff in a heterogeneous network environment. Furthermore, CSFB requires cost-intensive Mobile Switching Center (MSC) updates (Paisal, 2010b).

A further solution is the Voice over LTE via Generic Access (VoLGA) (Stepaniuk, 2010) that is based on the 3GPP Generic Access Network (GAN) (3GPP TS, 2009) standard and applies gateways to connect LTE to the existing MSC. This results in changing of the 3G network infrastructure where GAN enabled dual mode terminals are additionally needed. By considering circuit-switched calls in LTE, an IMS based Single Radio Voice Call Continuity (SRVCC) functionality has been proposed to move VoIP/IMS calls to 3G UMTS and vice versa (3GPP TS, 2008). However, this solution expects significant changes in operator's legacy core which slow down the immediate use of seamless voice call continuity in today's heterogeneous network infrastructure (Namakoye and Van Olst, 2011).

In Mehta et al. (2008a), the authors propose a PBX (Private Branch Exchange) based gateway concept as an independent network operator solution for seamless roaming between VoIP and circuit-switched based UMTS calls. For this purpose, the Call Forwarding Function of ISDN has been changed that does not meet the original standard anymore. The suggested Dynamically Anchored Conferencing Handoff (DACH) approach presumes that most calls are direct SIP-to-SIP conversations and the handoff of ongoing calls from WiFi to UMTS is only initiated by a third party (Smadi et al., 2008). The signaling channel to initiate handoffs is only reachable via WiFi using SIP. Moreover, the authors do not give operational details regarding the establishment of direct SIP-to-SIP calls.

To benefit at an earlier stage from seamless cloud voice services, we introduced in Daniel et al. (2009), Tran and Wietfeld, 2011, Tran et al., 2009 and Tran et al., 2012 a realizable and cost-effective Virtual Room based vertical handoff (VOOH) solution that has been deployed as prototype. One major strength of this Over-the-top solution is that VOOH only rides on top of the today's existing wireless heterogeneous networks (e.g., LTE, UMTS, WiFi). This has the nice property that the underlying network layers have not to be modified and thus lowers the integration cost compared to related solutions (e.g., SRVCC). A further advantage is that the independent network operator VOOH solution considers circuit-switched calls while handing over ongoing calls from VoIP via LTE/WiFi to 2G/3G. As a result, this improves the QoS for calls as opposed to packet-switched calls. Furthermore, VOOH also enables data-offloading (e.g., via WiFi) to lower the traffic load of cellular base stations.

Since VOOH is intended to be implemented as a cloud voice service, high availability and security aspects among other things