SERVICE CONSISTENCY FOR TODAY'S VoLTE SUBSCRIBERS

PROVIDING GLOBAL ACCESS WITH 4G LTE AND IMS CENTRALIZED SERVICES

TECHNOLOGY WHITE PAPER

End-user expectations for mobile services have evolved rapidly during the last two decades, and many subscribers now expect voice service to be globally available. Operators are therefore considering options for deploying IMS-based VoLTE with provisions for circuit-mode support where 4G LTE is not available. Standards organizations are defining IMS Centralized Services mechanisms to provide IMS-controlled voice service, even in legacy Circuit Switched networks. A fixed subset of common voice services can be offered to end users in mobile networks to provide voice service consistency across 4G LTE and 2G/3G CS network access without complex upgrades. With a more rapid launch of VoLTE enabled by simpler service consistency implementation, operators can gain a first-mover advantage and retain end users' interest and revenues.

TABLE OF CONTENTS

1. INTRODUCTION

Following successful deployments of telephony services based on IP Multimedia Subsystem (IMS) in fixed networks, IMS mobile telephony is now being deployed, driven by migration to all-IP Fourth Generation (4G) long term evolution (LTE) technology for mobile networks. End-user expectations for mobile services have evolved rapidly during the last two decades, and many end users now expect global availability of voice service through roaming. This presents a challenge for mobile IMS deployments because the core 4G LTE technology used to carry IMS is not yet globally available.

Standards organizations — notably Third-Generation Partnership Project (3GPP™) and the GSM Association (GSMA) — have taken up the challenge of defining mechanisms that can be employed to provide global availability of IMS-controlled voice services, even in legacy Circuit Switched (CS) networks. These mechanisms, called IMS Centralized Services (ICS), are elaborate. Each of the mechanisms works best only in specific network types, and with different tradeoffs: no common mechanism has been devised.

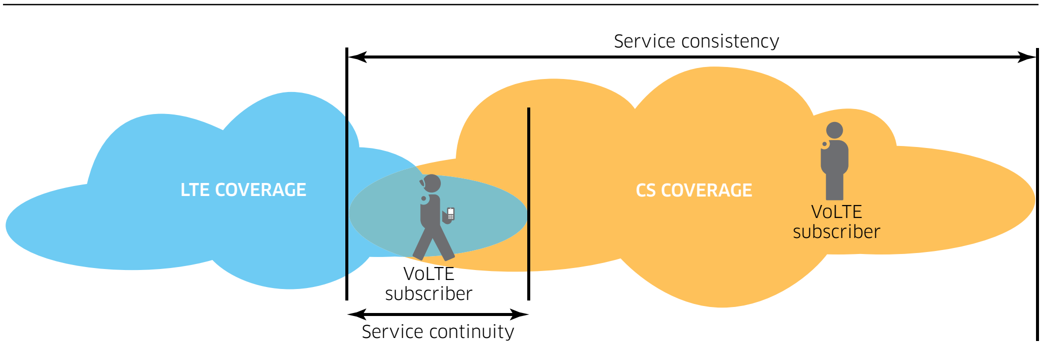
This paper describes a simpler approach to addressing the need for global access: instead of using elaborate mechanisms to maintain IMS-based control, define a fixed subset of common voice services that can be offered to end users in existing mobile networks, no matter where they are. The components of this approach are already described in recent documents from standards organizations such as 3GPP and the GSMA, and the required subset of voice services has already been defined. This subset is a convergence point for several different bodies of thought on the practical aspects of introducing the completely new 4G LTE mobile network capability, rather than a radically new approach.

This paper is targeted at those with some familiarity with the concepts underlying mobile networks — including 4G LTE and IMS — who are considering options for deploying IMS-based Voice over LTE (VoLTE).

2. SERVICE CONSISTENCY COMPARED TO SERVICE CONTINUITY

The focus of this paper is service consistency, but a similar-sounding term is service continuity. Service continuity refers to the techniques used to maintain an ongoing voice call when passing out of 4G LTE coverage and into legacy coverage. This process requires the handover of a VoLTE call — Voice over IP (VoIP) in 4G LTE — to legacy Second Generation/Third Generation (2G/3G) CS voice, as shown in Figure 1.

Figure 1. Service consistency and service continuity



Because service continuity applies to calls that transition from 4G LTE coverage to 2G/3G CS coverage, impacts to the legacy network are limited to areas near the edge of 4G LTE coverage. For example, for the style of service continuity known as Single Radio Voice Call Continuity (SRVCC), the 2G/3G CS Mobile Switching Centers (MSCs) must be upgraded, but the upgrade is limited to those MSCs that serve areas where the legacy network may pick up a call from the 4G LTE network. Even if the call continues into a portion of the legacy network that has not been upgraded, the controlling MSC remains the first one that acted on the call, at the edge of 4G LTE coverage.

With 3GPP Release 10, service continuity now includes MSC-assisted mid-call (MAM) capabilities for managing multiparty calls. MAM capabilities, if implemented, need only be provided in MSCs serving the edges of 4G LTE coverage.

Service consistency, the domain of ICS and the key topic of this paper, refers to the consistency of voice services availability across 4G LTE and legacy 2G/3G CS network access. Service consistency applies to a much broader range of calls, including calls originated from or terminated to an IMS subscriber even during legacy 2G/3G CS network coverage. An end user may be near or far from 4G LTE coverage and may even be roaming in a network that has no 4G LTE service. Service consistency mechanisms that assume MSC upgrades present a significant deployment challenge to operators of legacy networks.

3. SERVICE CONSISTENCY

The control mechanisms for services undergo a fundamental change in the migration from legacy 2G/3G CS voice to VoLTE. Home network control enables improved services for end users, regardless of where they roam. Readers who are familiar with home network control may want to skip to section 4.

3.1 Migration to home network control

In legacy 2G/3G CS networks, the foundation of service consistency is the use of a standardized[1] subscription record for the end user. This record, stored in the Home Location Register (HLR) of the home network, describes the service options and service states for an end user. The HLR record is provided using the Signaling System 7 (SS7) network to any MSC[2] that serves the end user. The voice service's logic therefore executes in the visited network's MSC: this is the visited control paradigm. Because the end user's HLR record is standardized, all MSCs offer consistent service.

The set of services offered in this fashion is static, fixed by the HLR standard that defines the end user's subscription record. Operators have limited flexibility to differentiate services, and differentiating mechanisms rely on additional software that executes in the visited MSC based on instructions from the home network, as is done with the Custom Applications for Mobile Networks Enhanced Logic (CAMEL) protocol.

1 Standardized across 3GPP networks or across 3GPP2 networks, but not between these network types
2 Technically, to the Visitor Location Register (VLR), which is then accessed by the MSC although it is common for the VLR to co-reside with the MSC.

3.2 Mobile service consistency in IMS-capable networks

Because IMS supports a much broader and more rapidly evolving suite of services that are integrated with voice service — including presence and mobile video — a more general paradigm is employed for mobile service consistency in IMS-capable networks. In the home control paradigm, an application server in the home network executes service logic[3] even if the end user is roaming. This permits an IMS operator to define unique and differentiated offerings that can be targeted to end users, provided that they are roaming to an IMS-capable network.

Not all 2G/3G networks are IMS-capable, and many are not able to support IMS VoIP because they lack the IP Quality of Service (QoS) controls required to guarantee the service performance requirements of voice. In these networks, the only choice is to offer voice using legacy 2G/3G circuit-mode MSCs, based on the home-network control paradigm.

This paradigm mismatch presents a challenge that can be addressed in one of two ways:

- Use 3GPP ICS, a suite of capabilities that extends IMS home control to end users served by MSCs.
- Select the key voice services that operate consistently on legacy 2G/3G CS networks while still offering advanced voice capabilities, such as high-definition audio and video calling, when end users are served by 4G LTE.

The industry is quietly converging on option 2 because no satisfactory approach has been found for option 1. Section 4 describes ICS and discusses how option 2 could be simply implemented at much lower cost than option 1.

4. STANDARDIZATION OF ICS ENHANCEMENTS

4.1 3GPP

3GPP is the source of standards-based alternatives for ICS. 3GPP Technical Specification (TS) 23.292 describes a toolbox of capabilities for producing differing levels of ICS over various types of CS networks. 3GPP has outlined two high-level approaches for ICS: User Equipment (UE) enhancements and MSC enhancements.

4.1.1 User Equipment enhancements

The approach based on UE (device) enhancements calls for the UE to maintain a signaling path to IMS in parallel with circuit-mode signaling to the MSC for voice calls. Two variants of UE enhancements, the "Gm" and "I1" variants, are named after architecture reference points. The Gm variant uses Session Initiation Protocol (SIP) signaling from the UE to IMS, the same as for 4G LTE access. The I1 variant encodes signaling in a form that is transmitted in networks that do not support simultaneous voice and data. The Gm and I1 variants extend IMS signaling to the device and therefore rely on an IMS client in the device.

3 Exceptions in the provision of service logic include emergency services and lawful intercept, which standards support in great detail.

4.1.2 MSC enhancements

The approach based on MSC enhancements, known as I2 ICS, requires the MSC to perform a new function: synthesizing the appropriate signaling between IMS signaling and circuit-mode TS 24.008 signaling from the handset. Although this approach can operate with any existing handset — it does not require an IMS client in the device — it cannot go beyond what an existing handset can do. Operators therefore face a fundamental investment question: “Why are we upgrading all our MSCs?” The answer, to achieve IMS centralization, is not inherently satisfying for the large up-front investment (driven by the requirement to retrofit all MSCs in the network with 3GPP ICS I2 software).

4.1.3 Market reaction to UE and MSC enhancements

Reaction in the marketplace to UE and MSC enhancements has been mixed. Vendors with a large embedded base of installed MSCs are naturally in favor of MSC enhancements because they understand the solution space, stand to win upgrade sales, and can bundle the cost of a 2G/3G network upgrade with a VoLTE deployment. Network operators have initially leaned toward the MSC enhancement approach to exploit the broadest possible ecosystem, but none is reported to have started investing in MSC upgrades for ICS. Some network operators have even decided to forgo 3GPP ICS in their initial VoLTE deployments. UE vendors have been largely on the sidelines, observing that they will build whatever the large operators want.

End users’ perceptions of value and relevancy for communication services are shifting toward alternative ecosystems provided by application and content providers (ACPs). Network operators that can quickly offer 4G LTE services, including VoLTE,[4] are likely to gain the first-mover advantage and retain end users’ interest and revenues.

4.2 GSMA

Recognizing that myriad options exist in IMS as well as in ICS, the GSMA has initiated several profiling efforts to specify a set of options for operators and equipment vendors. Two related GSMA Permanent Reference Documents (PRDs), IR.92 and IR.64, are key to this discussion.

GSMA PRD IR.92 defines the minimum set of mandatory features that must be supported by UE and network equipment. This minimum set is a subset of the 3GPP-specified MultiMedia Telephony service (MMTel) feature set and is also a subset of traditional legacy mobile services. Section 6 examines the PRD IR.92 service set in more detail.

GSMA draft PRD IR.64 provides guidelines for the implementation of ICS and service continuity. For ICS, IR.64 specifies network-based solutions — solutions involving MSC enhancements.[5] For MSCs that are not as enhanced, the IR.64 calls for CAMEL to anchor originating calls in IMS. No explicit mention is made of the possibility of an MSC that is not enhanced by or supports CAMEL: this case is covered in section 5. IR.64 describes the handover of VoLTE to legacy 2G/3G CS voice, service continuity, as mandatory for operators that provide 2G/3G CS coverage to complement their VoLTE service in 4G LTE.

4 Alcatel-Lucent. *IMS Communications: Inspire New Conversations*. http://www.alcatel-lucent.com/ims-communications/inspire-new-conversations.html

5 For ICS based on UE enhancements, current draft PRD IR.64 states, “The UE based IMS Centralized Services (ICS) solution is out of scope of this document and not recommended.” The document does not answer whether ICS is out of scope, not recommended, or both.

5. END-USER EXPERIENCE IN CS MODE

This section considers service consistency from the perspective of end users who are roaming in networks that support CS mode, or who are in a home network in which only CS mode is available. It is generally acknowledged[6] that an end user equipped for VoLTE will expect a single client: a single "app" for placing voice calls regardless of whether the voice call is carried over LTE or legacy CS. This is service consistency at its most fundamental level.

Beyond the client, an end user is likely aware of whether a call is being placed over 4G LTE or a legacy 2G/3G CS network:

- There are subtle audio cues: brief audio gaps (less than 300 ms) on handover from VoLTE to 2G/3G CS mode.
- The end user may perceive a reduction in voice quality after handover to 2G/3G CS mode. The recommended VoLTE coder/decoder (CODEC), Adaptive Multi-Rate Wideband (AMR-WB), is of higher fidelity than CODECs available in CS mode (AMR).
- Some options, such as video calls, are generally absent when operating in 2G/3G CS mode.

Beyond these cues, it is unlikely that end users would be able to perceive much about the exact 2G/3G CS network service on which they are operating when placing a voice call, and they have never had to in the past.

Enhanced ICS mechanisms are defined in ways that are sensitive to the underlying 2G/3G CS network technology. Depending on the mechanism, there may be sensitivity to:

- Presence or absence of MSC enhancements to support I2
- Ability of the MSC to support CAMEL
- Ability of the Radio Access Network (RAN) to support dual-transfer mode, single-transfer mode, or only circuit voice without simultaneous data services
- None of these distinctions is revealed by even subtle audio cues.

5.1 Classifying ICS modes

Specification of the complete range of network technologies requires a 4 x 3 table with 12 entries, with varying impacts on enhanced ICS mechanisms. However, end users do not care about which entry of the 4 x 3 table describes the network at their current location: they only care about whether they can count on consistent services. We therefore only need to look at the number of variations for each ICS mode:

- *Operator deploying MSC enhanced for ICS (ICS I2)* — In the abstract, the end user will see different behavior depending on the ability to anchor originations in the home network (for example, whether the serving MSC has MSC enhancements for ICS or CAMEL).

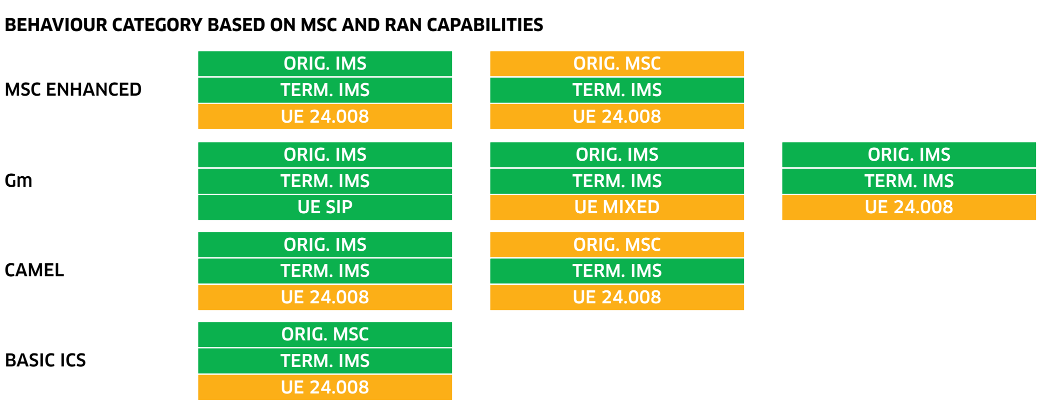
6 See, for example, 3GPP TS 23.292, Annex A.

- *Operator deploying UE enhanced for ICS (ICS Gm)* — In the abstract, the end user will see different behavior based on the RAN type: dual transfer, single transfer, or only circuit voice without simultaneous data. With dual transfer, all signaling is SIP; for single transfer, signaling is mixed: TS 24.008 while on a call and SIP while not on a call. For networks with only circuit voice without simultaneous data, signaling is exclusively TS 24.008.
- *Operator deploying CAMEL to anchor originations in IMS* — The end user will see behavior similar to MSC enhanced for ICS, depending on whether CAMEL is supported.
- *Operator relying on basic ICS capabilities* (those that only depend on fundamental MSC capabilities and that do not exploit CAMEL or MSC enhancements) — The end user will see only one variation: call originations processed in the MSC and call terminations processed in IMS.[7]

A "key" can be devised for each behavior variation, depending on each of three characteristics:
- Originations are anchored in IMS (green) or in the MSC (yellow).
- Terminations are anchored in IMS (green) or elsewhere (yellow).
- Signaling to the UE is based on SIP (green), TS 24.008 or a mix (yellow).

Each of these characteristics has a distinct impact on the end-user experience. For each of the ICS modes, the end user will likely experience the following "keyed" categories of voice service variation, as shown in Figure 2.

Figure 2. ICS behavior categories



This categorization assumes that an operator provisions a subscriber for a single ICS mode and that end users roam the world encountering various network types.

To the end user, any technique that presents variations in behavior is problematic. More troubling is that the underlying reasons for variations are not generally apparent to end users: for example, they will not know whether an MSC has been enhanced for I2 ICS.

Variations in voice service are therefore confusing to the end user. Only the simplest technique, basic ICS, exploits existing MSC capabilities and has just one variation. Section 6 examines whether basic ICS offers service consistency in CS mode and when operating in VoLTE.

7 The term *basic ICS* is not formally defined in standards and is ICS only in the sense that terminations continue to be centralized in IMS because of the way they are routed in the absence of other capabilities.

6. BASIC ICS AND VoLTE SERVICE CONSISTENCY

For MSC (basic) ICS, an analysis of the consistency of legacy 2G/3G CS services with their native counterparts in VoLTE requires a service-by-service view, referring to the services outlined in PRD IR.92. The analysis makes the following assumptions, based on known operator plans, standards documents and a few subtle design issues:

1. The HLR record is populated by the provisioning system consistently with population of the records that drive the operator's Telephony Application Server (TAS). As in TS 23.292, section 7.6.3.7.1, the 2G/3G CS network does not permit activation, deactivation or interrogation of supplementary services in the HLR. The HLR record is consequently static, and there is no mechanism to synchronize the HLR record with the Home Subscriber Server (HSS) data that is driving the TAS.
2. The HLR record shows call forwarding as disabled. Call forwarding acts on a terminating call and is executed in IMS because a terminating call enters IMS before being routed over the 2G/3G CS network.
3. In the few cases where this analysis assumes product capabilities, the capabilities of Alcatel-Lucent 4G LTE and VoLTE products are assumed to be from the Alcatel-Lucent End-to-End LTE LE5.0 release.
4. Call-barring settings can only be modified through the provisioning system.

Table 1 and Table 2 show the result of the analysis. A check mark in a column means that equivalent service is available. A check mark with a footnote denotes modest assistance in the service from the UE client, as detailed in the footnote.

Table 1 lists originating and terminating services. Originating services are processed in the MSC, based on the fixed HLR record. Terminating services are processed first in IMS by the TAS and then, if appropriate, in the MSC based on the fixed HLR record. The typical trigger to route terminating calls to IMS is an entry in the Mobile Number Portability (MNP) database that is made as a consequence of the end-user's subscription to VoLTE.

Table 1. Service equivalence for originating and terminating services

ORIGINATING/TERMINATING SERVICE	TYPE	EQUIVALENCE
Originating Identification Presentation (OIP)	Term.	✓
Terminating Identification Presentation (TIP)	Orig.	✓
Originating Identification Restriction (OIR)	Orig.	✓[8]
Terminating Identification Restriction (TIR)	Term.	✓
Communication forwarding unconditional	Term.	✓
Communication forwarding on busy	Term.	✓
Communication forwarding on not reachable	Term.	✓
Communication forwarding on no reply	Term.	✓
Barring of all incoming calls	Term.	✓
Barring of all outgoing calls	Orig.	✓
Barring of outgoing international calls	Orig.	✓
Barring of outgoing international calls outside home country	Orig.	✓
Barring of incoming calls when roaming	Term.	✓

8 The UE client must remember the most recent setting of OIR and signal it at call setup.

For mid-call and presentation services, there is no distinction between originating and terminating services and their logic. Table 2 shows these services.

Table 2. Service equivalence for mid-call and presentation services

SERVICE	EQUIVALENCE
Communication hold	✓
Message waiting indication	✓
Communication waiting	✓[9]
Ad hoc multi-party conference	✓

The equivalence between PRD IR.92 services offered in legacy mode and the same services offered in IMS mode can be quite high although in two cases some functionality is required by the common client to ensure equivalent operation. This result is quite surprising, particularly given the amount of industry effort that has been spent on alternatives for IMS centralized services. Service consistency is therefore high if CS mode voice is restricted to just the functionality specified by the PRD IR.92 MMTEL services.

VoLTE IMS can be used to provide home-network extensible services. If such a service is intended for operation in 2G/3G CS mode, additional careful analysis would be required to understand 2G/3G CS mode operation. As a general rule, if the service is a terminating service, it will probably work in 2G/3G CS mode: terminating services are processed by IMS first, before entering the 2G/3G CS network. Originating and mid-call services are more complex.

The UE capabilities footnoted in Tables 1 and Table 2 avoid the need to synchronize the HSS database that is driving IMS with the HLR database that is controlling CS services. Other approaches can achieve the same effect, but the outlined approach is the simplest we have seen.

The real benefit comes from the result of the prior section: staying with this set of services yields consistent operation of the services in any network, without complex network upgrades.

9 In legacy mode, if the end user has temporarily disabled call waiting, the UE must signal busy if a second call arrives.

7. OPEN ISSUES AND THE FUTURE

While the preceding sections show that no special network functionality is required for ICS for a set of voice services, a question remains about non-voice services: services that may not yet have been developed. It may be desirable for these services to operate using IMS in 2G or 3G Packet Switched (PS), subject to QoS capabilities that may or may not be deployed in 2G/3G. Some services, such as presence and Instant Messaging (IM), do not need QoS in 2G/3G PS networks. Other services, such as VoIP or video communications in 3G Evolved High-Speed Packet Access (HSPA+), require QoS to assure end users' satisfactory service experience.

VoIP and video communications both require native IMS connections over the PS network, which will by practical necessity terminate in the same client as the network that is handling voice services. The implementation of such services is similar to ICS in Gm mode, including using an IMS client in the device. These services may therefore drive interest in ICS Gm mode services.

For other ICS modes, the Alcatel-Lucent 4G Consumer Communications Solution introduced CAMEL anchoring of originations and is already available. ICS based on MSC and UE enhancements is planned, with considerable design work already complete. Commercial viability of these modes depends on the global ecosystem's implementation across operators, device manufacturers and network equipment vendors.

8. CONCLUSION

An analysis of PRD IR.92 VoLTE services shows that the critical subscriber-experience goal of service consistency is readily provided to VoLTE end users who are served by 2G/3G CS networks by using only the basic ICS capabilities that are built on standard, ubiquitous MSC capabilities. Although ICS continues to be of interest in the technical community, operators may chose to delay the introduction of enhanced ICS modes (Gm, I1, I2) until a more compelling need appears.

In particular, a basic ICS approach allows an operator to deploy VoLTE without broad upgrades of MSCs to support ICS. With a basic ICS approach, MSC upgrades are limited to the minimal set of upgrades required to support service continuity at the edge of LTE coverage, using SRVCC for the handover of VoLTE to 2G/3G CS voice.

9. ACRONYMS

2G, 3G, 4G	Second Generation, Third Generation, Fourth Generation
3GPP	Third-Generation Partnership Project
ACP	application and content provider
AMR-WB	Adaptive Multi-Rate Wideband
CAMEL	Customized Applications of Mobile Enhanced Logic
CS	Circuit Switched
GSMA	Global System for Mobile Communications Association
HLR	Home Location Register
HSPA+	Evolved High-Speed Packet Access
HSS	Home Subscriber Server
ICS	IMS Centralized Services
IM	Instant Messaging
IMS	IP Multimedia Subsystem
LTE	long term evolution
MAM	MSC-assisted mid-call
MMTel	3GPP MultiMedia Telephony service
MNP	Mobile Number Portability
MSC	Mobile Switching Center
PRD	Permanent Reference Document
PS	Packet Switched
QoS	Quality of Service
RAN	Radio Access Network
SIP	Session Initiation Protocol
SRVCC	Single Radio Voice Call Continuity
SS7	Signaling System 7
TAS	Telephony Application Server
TS	Technical Specification
UE	User Equipment
VLR	Visitor Location Register
VoIP	Voice over IP
VoLTE	Voice over LTE

10. REFERENCES

1. 3GPP. TS 22.173: *IP Multimedia Core Network Subsystem (IMS) Multimedia Telephony Service and supplementary services*; Stage 1. 2010.
2. 3GPP. TS 23.292: *IP Multimedia Subsystem (IMS) centralized services; Stage 2*. 2011.
3. 3GPP. TS 24.008: *Mobile radio interface Layer 3 specification; Core network protocols; Stage 3*.
4. Alcatel-Lucent. *IMS Communications: Inspire New Conversations*. http://www.alcatel-lucent.com/ims-communications/inspire-new-conversations.html
5. GSMA. PRD IR.92: *IMS Profile for Voice and SMS. December 2010*.
6. GSMA. PRD draft IR.64, *IMS Services Centralization and Continuity Guidelines*. July 2011.

Alcatel·Lucent