WILEY

Voice over LTE
VoLTE

Miikka Poikselkä
Harri Holma
Jukka Hongisto
Juha Kallio
Antti Toskala

VOICE OVER LTE

VOICE OVER LTE

VoLTE

Miikka Poikselkä, Harri Holma, Jukka Hongisto,
Juha Kallio and Antti Toskala
Nokia Siemens Networks, Finland

WILEY
A John Wiley & Sons, Ltd., Publication

This edition first published 2012

Registered office
John Wiley & Sons Ltd, The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, United Kingdom

Library of Congress Cataloging-in-Publication Data

Poikselkä, Miikka.
Voice over LTE (VoLTE) / Miikka Poikselkä, Harri Holma, Jukka Hongisto, Juha Kallio and Antti Toskala.
pages cm
Includes bibliographical references and index.
ISBN 978-1-119-95168-1
1. Long-Term Evolution (Telecommunications) 2. Internet telephony. I. Holma, Harri, 1970- II. Hongisto, Jukka. III. Kallio, Juha. IV. Toskala, Antti. V. Title.
TK5103.48325.P65 2012
621.3845′6–dc23

2011047199

A catalogue record for this book is available from the British Library.

Print ISBN: 9781119951681

Set in 10/12 Times by Laserwords Private Limited, Chennai, India

Contents

Preface

Voice communication has become mobile in a massive way and the mobile is the preferred way for voice communication for more than six billion subscribers. The introduction of high speed packet access (HSPA) also allows a large set of data services from smartphones, tablets and laptops to go mobile. The data volumes in mobile networks greatly exceed the voice volumes – from the traffic point of view, networks have already turned from voice dominated to data dominated. The next generation mobile radio system, called long term evolution (LTE), started commercially in 2009 and is designed to boost further the data rates and capacities. LTE radio is primarily optimised for high capacity data but can also support voice efficiently. During 2012, smartphones with the capability to provide a voice service using the LTE network are becoming available. This book describes how the voice service is supported with LTE capable terminals. The voice support in LTE is not as trivial as in second generation (2G) GSM and third generation (3G) WCDMA solutions where circuit switched (CS) voice was used, since LTE is designed only for packet switched (PS) connections. The voice service in LTE uses the voice over Internet protocol (VoIP) – called VoLTE (voice over LTE) – together with the IP multimedia system (IMS). There are also alternative solutions for supporting voice in the initial phase where the voice service runs on legacy 2G/3G networks while only data is carried on LTE. The voice solutions, architectures and required functionalities are described in this book.

The book is structured as follows. Chapter 1 gives the background and Chapter 2 describes the operator VoLTE deployment strategies. The system architecture is presented in Chapter 3 and VoLTE functionalities in Chapter 4. End to end signalling is illustrated in Chapter 5 and IMS centralized services in Chapter 6. The VoLTE radio performance is presented in Chapter 7 and the VoIP over HSPA networks in Chapter 8.

LTE will access a very large global market – not only GSM/WCDMA operators, but also CDMA and WiMAX operators and potentially also fixed network service providers. The large potential market can attract a large number of companies to the market place pushing the economics of scale, which enables wide scale LTE adoption with lower cost. The voice solution is a key part of the system design – every single LTE capable smartphone needs to have a good quality voice solution. This book is particularly designed for chip set and mobile vendors, network vendors, network operators, technology managers and regulators who would like to get a deeper understanding of voice over LTE.

Acknowledgements

We would like to thank the following colleagues for their valuable comments: Jari Välimäki, Peter Leis, Curt Wong and Martin Öttl.

The authors appreciate the fast and smooth editing process provided by John Wiley & Sons Ltd and especially Susan Barclay, Sandra Grayson, Sarah Tilley, Sophia Travis and Mark Hammond.

We are grateful to our families for their patience during the late night and weekend editing sessions.

The authors welcome any comments and suggestions for improvements or changes that could be used to improve future editions of this book. The feedback is welcomed to the authors' email addresses - miikka.poikselka@nsn.com, harri.holma@nsn.com, jukka.hongisto@nsn.com, juha.kallio@nsn.com and antti.toskala@nsn.com.

List of Abbreviations

1×RTT	Single carrier radio transmission technology
3GPP	Third generation partnership project
3GPP2	Third generation partnership project 2
AAA	Authentication, authorization and accounting
AAL	ATM adaptation layer
AAR	AA request
ACA	Accounting answer
ACK	Acknowledgement
ACR	Accounting request
AGCF	Access gateway control function
A-GNSS	Assisted global navigation satellite system
AGW	Access gateway
AKA	Authentication and key agreement
ALG	Application level gateway
AMR	Adaptive multi-rate
AMR-WB	Adaptive multi-rate wideband
AOC	Advice of charge
AP	Authentication proxy
APN	Access point name
APN-AMBR	Access point name–aggregate maximum bit rate
ARP	Allocation and retention priority
AS	Application server
ASA	Abort session answer
ASR	Abort session request
ATCF	Access transfer control function
ATGW	Access transfer gateway
ATM	Asynchronous transfer mode
AUC	Authentication centre
AUID	Application usage identification
AUTN	Authentication token

AVC	Advanced video coding
AVP	Attribute value pair; audio visual profile
AVPF	Audio visual profile with feedback
B2BUA	Back to back user agent
BGCF	Breakout gateway control function
BICC	Bearer independent call control
BS	Billing system
BSC	Base station controller
BSS	Base station system
BTS	Base transceiver station
CAT	Customized alerting tone
CB	Communication barring
CCBS	Completion of communications to busy subscriber
CCF	Charging collection function
CCNR	Completion of communications on no reply
CD	Communication deflection
CDF	Charging data function
CDMA	Code division multiple access
CDR	Charging data record
CLI	Calling line identification
CN	Core network
CSFB	Circuit switched fallback
DCH	Dedicated traffic channel
PCH	Paging channel
CFB	Communication forwarding busy
CFNL	Communication forwarding on not logged in
CFNR	Communication forwarding no reply
CFNRc	Communication diversion on mobile subscriber not reachable
CFU	Communication forwarding unconditional
CGF	Charging gateway function
CGI	Cell global identification
CK	Ciphering key
CLIP	Calling line identification presentation
C-MSISDN	Correlation mobile subscriber international ISDN number
CONF	Conference calling
CPC	Continuous packet connectivity
CPE	Customer premise equipment
CRS	Customized ringing signal
CS	Circuit switched
CSCF	Call session control function
CSFB	Circuit switched fallback
CSMO	Circuit switched mobile originating
CTF	Charging trigger function

CUG	Closed user group
CW	Communication waiting
DCH	Dedicated channel
DFCA	Dynamic frequency and channel allocation
DL	Downlink
DNS	Domain name system
DOCSIS	Data over cable service interface specification
DPCCH	Dedicated physical control channel
DPDCH	Dedicated physical data channel
DRB	Data radio bearer
DRX	Discontinuous reception
DTAP	Direct transfer application part
DTM	Dual transfer mode
DTMF	Dual-tone Multi-frequency
DTX	Discontinuous transmission
EATF	Emergency access transfer function
ECF	Event charging function
ECM	Evolved packet system connection management
E-CSCF	Emergency CSCF
ECT	Explicit communication transfer
E-DCH	Enhanced dedicated channel
EDGE	Enhanced data rates for global evolution
EFR	Enhanced full rate
eHRPD	Evolved high rate packet data
EMM	Evolved packet system mobility management
eMSS	Enhanced mobile switching centre server
eNB	Evolved nodeB
eNodeB	Evolved nodeB
EPC	Evolved packet core
ePDG	Evolved packet data gateway
EPS	Evolved packet system
E-SMLC	Evolved serving mobile location centre
E-STN-SR	Emergency session transfer number for SRVCC
ETSI	European Telecommunications Standards Institute
E-UTRAN	Evolved universal mobile telecommunications system terrestrial radio access network
EV-DO	Evolution data only
FA	Flexible alerting
FGI	Feature group indicator
FoR	Follow on request
FTP	File transfer protocol
GAA	Generic authentication architecture
GBR	Guaranteed bit rate
GERAN	Global system for mobile communications/EDGE radio access network

GGSN	Gateway general packet radio service support node
GMLC	Gateway mobile location centre
GPRS	General packet radio service
GPS	Global positioning system
GRUU	Globally routable user agent URI
GSM	Global system for mobile communications
GSMA	GSM association
GTP	GPRS tunnelling protocol
GTP-C	GPRS tunnelling protocol control plane
GTP-U	GPRS tunnelling protocol user plane
GWF	Gateway function
HARQ	Hybrid automatic repeat request
HLR	Home location register
HOLD	Communication hold
HPLMN	Home public land mobile network
HRPD	High rate packet data
HSDPA	High speed downlink packet access
HS-DSCH	High speed downlink shared channel
HSGW	HRPD serving gateway
HSPA	High speed packet access
HSS	Home subscriber server
HSUPA	High speed uplink packet access
HTTP	Hyper text transfer protocol
IAM	Initial address message
IBCF	Interconnection border control function
ICID	Internet protocol multimedia subsystem charging identifier
ICS	Internet protocol multimedia subsystem centralised services
I-CSCF	Interrogating CSCF
ICSI	Internet protocol multimedia subsystem communication service identification
IETF	Internet engineering task force
iFC	Initial filter criteria
IK	Integrity key
IM	Instant messaging
IMEI	International mobile equipment identity
IMPI	IMS private user identity
IMPU	Internet protocol multimedia subsystem public user identity
IMS	Internet protocol multimedia subsystem
IMSI	International mobile subscriber identifier
IMS-MGW	IMS media gateway
IM-SSF	Internet protocol multimedia service switching function

IMTC	International multimedia teleconferencing consortium
IOI	Inter-operator identifier
IP	Internet protocol
IP-CAN	IP connectivity access network
IP-PBX	IP private branch exchange
IPsec	Internet protocol security
IP-SM-GW	IP short message gateway
IPv4	Internet protocol version 4
IPv6	Internet protocol version 6
ISC	IMS service control
ISDN	Integrated services digital network
ISIM	IP multimedia services identity module
ISR	Idle mode signaling reduction
ISUP	ISDN user part
LAI	Location area identity
LCS	Location control services
LIA	Location info answer
LIR	Location info request
LRF	Location retrieval function
LTE	Long term evolution
MAA	Multimedia–multimedia answer
MAC	Medium access control
MaM	Mid-call assisted mobile switching centre server
MAP	Mobile application part
MAR	Multimedia authorisation request
MBR	Maximum bit rate
MCC	Mobile country code
MCID	Malicious communication identification
ME	Mobile equipment
MGCF	Media gateway control function
MGW	Media gateway function
MIME	Multipurpose Internet mail extension
MI-USSD	Mobile initiated unstructured supplementary service data
MME	Mobility management entity
MMS	Multimedia messaging service
MMTel	Multimedia telephony communication service
MNC	Mobile network code
MO-LR	Mobile originating location request
MRB	Media resource broker
MRFC	Multimedia resource function controller
MRFP	Media resource function processor
MSC	Mobile switching centre
MSIN	Mobile subscriber identification number
MSISDN	Mobile subscriber ISDN

MSRN	Mobile station roaming number
MSRP	Message session relay protocol
MSS	MSC server
MT-LR	Mobile terminating location request
MTP	Message transfer part
MTRF	Mobile terminating roaming forwarding
MTRR	Mobile terminating roaming retry
MTU	Maximum transmission unit
MWI	Message waiting indication
NACC	Network assisted cell change
NAI	Network access identifier
NAS	Network access stratum
NAT	Network address translator
NB	Narrowband
NDS	Network domain security
NGMN	Next generation mobile networks alliance
NGN	Next generation network
NI-USSD	Network initiated unstructured supplementary service data
NW	Network
OCS	Online charging system
OFDMA	Orthogonal frequency division multiple access
OIP	Originating identification presentation
OIR	Originating identification restriction
OMA	Open mobile alliance
OSA	Open service architecture
OTDOA	Observed time difference of arrival
PCC	Policy and charging control
PCEF	Policy enforcement function
PCRF	Policy and charging rules function
P-CSCF	Proxy-CSCF
PDCCH	Physical downlink control channel
PDCP	Packet data convergence protocol
PDN	Packet data network
PDP	Packet data protocol
PDSCH	Physical downlink shared channel
P-GW	PDN gateway
PHY	Physical layer
PLMN	Public land mobile network
PNM	Personal network management
PoC	Push to talk over cellular
POTS	Plain old telephone service
PRACK	Provisional response acknowledgement
PRN	Provide roaming number
PS	Packet switched; presence server
PS HO	Packet switched handover

PSAP	Public safety answering point
PSTN	Public switched telephone network
QCI	QoS class identifier
QoS	Quality of service
RAA	Re-authorisation request
RAB	Radio access bearer
RAN	Radio access network
RAND	Random challenge
RAR	Re-authorisation request
RAT	Radio access technology
RCS	Rich communication suite
RDF	Routing determination function
RES	Response
RF	Radio frequency
RFC	Requests for comments
RLC	Radio link control
RNC	Radio network controller
RoHC	Robust header compression
RR	Receiver reports
RRC	Radio resource control
RSH	Resume call handling
RSRP	Reference symbol received power
RSRQ	Reference signal received quality
RTCP	Real-time transport protocol control protocol
RTP	Real-time transport protocol
RTP/AVP	RTP audio and video profile
S1AP	S1 application protocol
SA	Security association
SAA	Server assignment answer
SAE	System architecture evolution
SAI	Service area identifier
SAR	Server assignment request
SCC AS	Service centralisation and continuity application server
SCCP	Signalling connection control part
SC-FDMA	Single carrier FDMA
S-CSCF	Serving CSCF
SCTP	Stream control transmission protocol
SDP	Session description protocol
SEG	Security gateway
SGsAP	SGs application part
SGSN	Serving GPRS support node
S-GW	Serving gateway
SIB	System information block
SIM	Subscriber identity module
SIP	Session initiation protocol

SLF	Subscription locator function
SM	Short message
SMS	Short message service
SMSC	Short message service centre
SPR	Subscription profile repository
SPS	Semi persistent scheduling
SPT	Service point trigger
SQN	Sequence number
SR-VCC	Single radio voice call continuity
SRVCC	Single radio voice call continuity
SUPL	Secure user plane location
SV-DO	Simultaneous voice and data only
SV-LTE	Simultaneous voice and LTE
TA	Tracking area
TAI	Tracking area identity
TAS	Telephony application server
TCP	Transmission control protocol
TFT	Traffic flow template
THIG	Topology hiding inter-network gateway
TIP	Terminating identification presentation
TIR	Terminating identification restriction
TISPAN	Telecommunications and Internet converged services and protocols for advanced networking
TLS	Transport layer security protocol
TLV	Tag length value
TMR	Transport medium requirement
TMSI	Temporary mobile subscriber identity
TrGW	Transition gateway
TTI	Transmission time interval
UA	User agent
UDP	User datagram protocol
UE	User equipment
UE-AMBR	UE aggregate maximum bit rate
UICC	Universal integrated circuit card
UL	Uplink
UM	Unacknowldeged mode
UMTS	Universal mobile telecommunications system
URA	UTRAN registration area
URI	Uniform resource identifier
URL	Universal resource locator
USI	User service information
USIM	Universal subscriber identity module
USSD	Unstructured supplementary service data
USSI	Unstructured supplementary services data simulation in IMS
UTDOA	Uplink time difference of arrival

UTRAN	UMTS terrestrial radio access network
VLR	Visitor location register
VMSC	Visited MSC
VoIP	Voice over IP
VoLGA	Voice over LTE via generic access
VoLTE	Voice over LTE
VPLMN	Visited PLMN
WCDMA	Wideband code division multiple access
WLAN	Wireless local area network
XCAP	XML configuration access protocol
XDM	XML document management
XDMS	XML document management server
xDSL	Digital subscriber line
XML	Extensible markup language
XRES	Expected response

1

Background

At the end of 2004 the third generation partnership project (3GPP) Standardisation Forum started to evaluate a new radio technology as a successor for wideband code division multiple access (WCDMA). This work was called long term evolution (LTE) and is nowadays the radio interface name used in most official publications. Inside 3GPP the newly developed radio access network is called the evolved UMTS terrestrial radio access network (E-UTRAN) to indicate the path from the global system for mobile communications (GSM)/Enhanced data rates for global evolution (EDGE) radio access network (GERAN) via the GSM/general packet radio service (GPRS)/EDGE to UTRAN [WCDMA/high-speed packet access (HSPA)] and finally to E-UTRAN (LTE). In parallel to the work on a new radio interface 3GPP initiated a study to evolve the 2G/3G packet core network (known as the GPRS core) in order to cope with the new demands of LTE. This core network study was called system architecture evolution (SAE) and it was documented in the 3GPP technical report (3GPP TR 23.882). The final outcome of this work was a new packet core design in Release 8 documented in (3GPP TS 23.401) and (3GPP TS 23.402), called the evolved packet core (EPC). 3GPP Release 8 was officially completed in March 2009 and the world's first commercial LTE network was opened in December 2009 by TeliaSonera.

3GPP Release 8 introduces major advances in mobile networks. For the subscriber, it means higher access rates and lower latency on the connection, while for the mobile communication service provider, LTE radio technology provides lower cost per transmitted bit thanks to more efficient use of radio network resources and delivers excellent voice spectral efficiency, as described in Chapter 7. The technology also offers more flexibility in frequency allocation, thanks to the ability to operate LTE networks across a very wide spectrum of frequencies. LTE also minimises the power consumption of terminals that are used 'always on'. 3GPP Release 8 also introduces major advances in the core network that improve service quality and networking efficiency, leading to a better end user experience. GPRS technology has already introduced the always on concept for subscriber connectivity and 3GPP Release 8 mandates this ability, with at least one default bearer being always available for all subscribers. This allows fast access to services as well as network initiated services such as terminating voice calls and push e-mail. The connection setup time for person to person communication is also minimised with always on bearers.

Voice over LTE: VoLTE, First Edition. Miikka Poikselkä, Harri Holma, Jukka Hongisto, Juha Kallio and Antti Toskala.

But considering the fact that LTE is an all-internet protocol (IP) technology we can get to the conclusion that the voice service will have to be delivered in a different way as circuit switched voice will not be possible. So there is a need for a voice solution on top of LTE. Voice in this IP world, would be implemented as voice over Internet protocol (VoIP). The 3GPP-specified way to support VoIP is the IP multimedia subsystem (IMS). It is an access-independent and standard-based IP connectivity and service control architecture that enables various types of multimedia services to end users using common Internet-based protocols. 3GPP has worked with the IMS since 2000 and there exist thousands of pages, in different specifications, that cover IMS related functionalities. In the meantime, a sophisticated architecture and feature set has been developed. Moreover, 3GPP has specified multiple, different ways to complete single functions (e.g. authentication, session setup, supplementary service execution, bearer setup) which increases complexity of the IMS.

While 3GPP has specified all of the 'ingredients' needed to implement IMS-based voice over long term evolution (VoLTE) – such as session initiation protocol (SIP) registration, signalling compression, call set up and supplementary services – it has left it up to communication service providers and vendors to decide which of the numerous alternative implementation options to use. This is frankly a recipe for a chaotic and fragmented rollout of IMS-based VoLTE since there is no way to guarantee that different industry players will opt for the same 'ingredients' that their competitors' choose for their own implementations. It goes without saying it was not a model for success.

Unsurprisingly, in the absence of a clear-cut approach to VoLTE, alternatives emerged, most notably 3GPP specified circuit switched fallback (CSFB), in which an communication service provider uses its legacy 2G/3G network to handle voice calls. In this scenario, when an LTE terminal initiates a voice call or receives one from the legacy circuit-switched network, it downgrades any ongoing LTE data session to 3G or HSPA speeds for the duration of the voice call. If the voice call 'falls back' to a 2G network, the LTE data session will likely be suspended altogether, as 2G data speeds are not sufficient for broadband data applications. In either case, the impact on customer experience can be obvious.

Another emerged alternative for IMS-based VoLTE was VoLTE via generic access (VoLGA) promoted by the VOLGA Forum.

All major network and handset vendors compete aggressively for the biggest possible slice of network communication service providers' business. But at the same time, their business is an interconnected business, where equipment interoperability, especially between handset and network is the key to ensuring that they can all play together. For communication service providers voice have been the killer application and it is going to be big source of revenue for years to come. When there were three different voice solutions (IMS-based VoIP, CSFB, VoLGA) there was rightfully serious concerns whether LTE would come with voice anytime soon. So the situation in year 2009 was equally challenging for both communication service providers and vendors. This is why, from time to time, serious rivals come together to agree on technical cooperation that is designed to help smooth the way forward for the common good of the telecoms market. On 4 November 2009 the One Voice initiative was published by AT&T, Orange, Telefonica, TeliaSonera, Verizon, Vodafone, Alcatel-Lucent, Ericsson, Nokia Siemens Networks, Nokia, Samsung and Sony Ericsson. These 12 companies announced that they have concluded that the IMS-based solution, as defined by 3GPP, is the most applicable approach to meet their consumers' expectations for service quality, reliability and availability when moving from

existing circuit switched telephony services to IP-based LTE services. The companies in One Voice then set about to create a solid foundation for securing the smooth introduction of standards-based VoLTE. They evaluated the different alternative 'ingredients' specified by 3GPP in order to settle on a minimum set of essential handset and network functionalities and features that communication service providers would need to implement basic, interoperable VoLTE service. These agreed mandatory set of functionalities for the user equipment (UE), the LTE access network, the EPC network and the IMS functionalities are contained in the 'technical profile' published by One Voice, available for use by anyone in the industry. In a sense, the technical profile gives all industry stakeholders a level playing field on which to enhance their VoLTE service as they see fit, but most importantly a level playing field that enables the basic working, and interworking, of VoLTE across the entire industry landscape.

15 February 2010 marks the second important milestone in VoLTE ecosystem development. On that date, the Global System for Mobile Association (GSMA) announced it has adopted the work of the One Voice initiative to drive the global mobile industry towards a standard way of delivering voice and messaging services for LTE (GSMA) and Next Generation Mobile Networks alliance (NGMN) delivered communication service providers' agreement to ensure roaming for VoLTE by recommending to support CSFB in all LTE voice devices and networks (NGMN). The GSMA's VoLTE initiative was supported by more than 40 organisations from across the mobile ecosystem, including many of the world's leading mobile communication service providers, handset manufacturers and equipment vendors, all of whom support the principle of a single, IMS-based voice solution for next-generation mobile broadband networks. This announcement was also supported by 3GPP, NGMN and the International Multimedia Teleconferencing Consortium (IMTC). Following the announcement, work progressed very quickly; and already in March 2010 the GSMA permanent reference document (IR.92) on IMS profile for voice and short message service (SMS) was published containing an improved version of the One Voice profile. In September 2010 GSMA agreed to freeze the content of the permanent reference document (IR.92). A global baseline for commercial VoLTE deployments was finally stabilised.