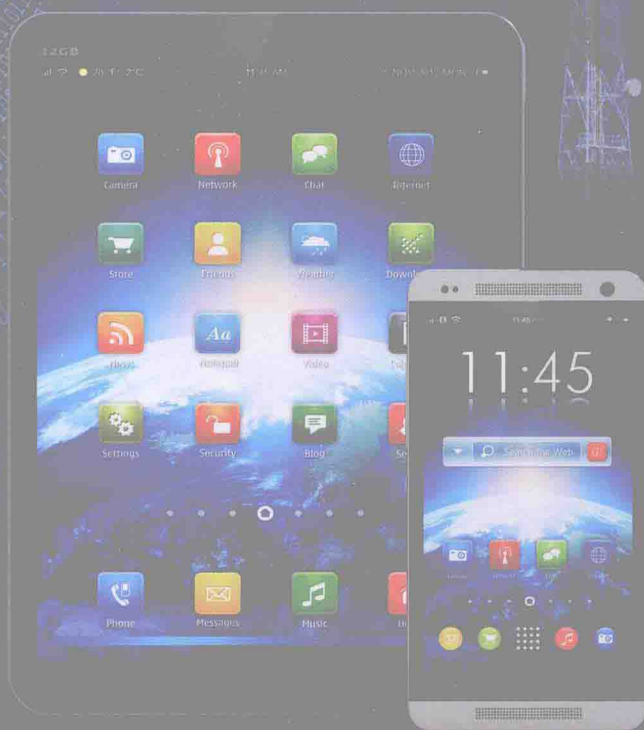


The LTE-Advanced Deployment Handbook

The Planning Guidelines for the
Fourth Generation Networks



Editor

Jyrki T. J. Penttinen

WILEY

THE LTE-ADVANCED DEPLOYMENT HANDBOOK

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FOR THE FOURTH
GENERATION NETWORKS

Edited by

Jyrki T. J. Penttinen

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Preface

Mobile communications technologies are developing in giant leaps especially in the current LTE era. The initial phase of the enhanced 3G system driven by 3GPP resulted in LTE/SAE, as defined in Release 8. It has already opened doors for a much more fluent user experience, thanks to the considerably higher data rates and lower response times compared to any other previous cellular system. The first LTE deployments took place in 2010–11, and the pace has been breathtaking ever since. According to 4G Americas (www.4gamericas.org), there were 755 Million LTE subscribers by June 2015, which proves there is high demand for mobile data.

Further development has resulted in the 3GPP Release 10 standards which represent the first set for the LTE-Advanced (LTE-A) system. The ITU (International Telecommunications Union) has defined demanding criteria for the use of the term 4G, including requirements for the capability of the mobile network to transfer a minimum of 1 Gb/s data rate in the downlink. 3GPP LTE in Release 10 starts to include enough components that jointly contribute to the total performance so efficiently that it can already be called an ITU-compliant 4G system. In practice, the term 4G has been used already for some time to distinguish even between basic LTE and the previous 3G variants. This market interpretation is of course justified as the LTE as such opens the door to the next generation via the gradual upgrading of the network and user device functionalities. Nevertheless, in this book, the term 4G refers to the 3GPP LTE Release 10 and beyond, while earlier LTE variants in Release 8 and 9 are referred to in this book as “evolved 3G, or pre-4G” systems.

At the time of writing, there have already been 32 LTE-Advanced networks in 23 countries by the end of 2014, according to 4G Americas. The deployments are still expanding so it can be expected that Release 10 and beyond networks will be widely available for we mobile users to enjoy fluent connectivity and to consume high-quality multimedia contents globally easier than ever.

Observing all the accelerating developments of mobile communications technologies, it is in fact almost impossible to keep track of the advances even in real-time web discussion forums. Nevertheless, I believe it is totally justified to summarize technical areas in a single package, as *The LTE-Advanced Deployment Handbook* aims to do, to aid studies in capturing the complete picture and the key set of relevant details. Even with the further advances beyond this book contents, the basics described here will be an important building block for the investigations of the next releases. As an additional aim to ensure the contents of this book are up to date, there also are updates provided in www.tlt.fi which collects further key data and useful information about the development of LTE and LTE-Advanced systems.

This book is the result of innumerable hours of work by the team, and there are many highly relevant real-world experiences behind each chapter. I hope our creation of this information package on LTE-Advanced principles, functionality and planning has been worth the effort and you will find it useful in your studies and work. As was the case with the previous *LTE/SAE Deployment Handbook*, published by Wiley in 2011, I would be glad to receive your valuable feedback about this book directly via my e-mail address jyrki.penttinen@hotmail.com.

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Acknowledgments

The LTE-Advanced Deployment Handbook is a follow-on to the previously published *LTE/SAE Deployment Handbook* which describes key aspects of the initial LTE phase. This *LTE-Advanced Deployment Handbook* details the now essential functionality of the system and provides planning guidelines for the developed phase of LTE in Release 10 and beyond.

This book is the result of our contributor team's efforts as well as our collaboration with many LTE subject matter experts and seasoned professionals. I would like to thank the whole team and the participating colleagues for the most valuable information sharing and contribution, often sacrificing their precious private time. I know that the team has succeeded excellently in our mission to provide an up-to-date, practical and useful guide for both academic as well as operational LTE-Advanced environments.

Warm thanks go to the Wiley team which guided and made sure the project was finalized successfully; I want to give my special thanks to Mark Hammond, Sandra Grayson, Teresa Netzler, Sarah Keegan and Clarissa Lim, and all others from the Wiley team who have worked on this project, as well as Shikha Pahuja at Thomson Digital.

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Jyrki Penttinen

Abbreviations

2G	Second Generation of mobile communication technologies
3G	Third Generation of mobile communication technologies
3GPP	3rd Generation Partnership Project
4G	Fourth Generation of mobile communication technologies
16-QAM	16-state Quadrature Amplitude Modulation
64-QAM	64-state Quadrature Amplitude Modulation
AAA	Authentication, Authorization & Accounting
AAS	Active/Adaptive Antenna System
ABS	Almost Blank Subframes
AC	Admission Control
ACIR	Adjacent Channel Interference Rejection
ACK	Acknowledgment
ACLR	Adjacent Channel Leakage Ratio
ACS	Adjacent Channel Selectivity
ACS	Advanced Communications Services
ADC	Analogue/Digital Conversion
ADSL	Asynchronous Digital Subscriber Line
AF	Application Function
A-GNSS	Assisted Global Navigation Satellite System
aGW	Access Gateway
AKA	Authentication and Key Agreement
AMBR	Aggregated Maximum Bit Rate
AMC	Adaptive Modulation and Coding
ANDSF	Access Network Discovery and Selection Function
ANR	Automatic Neighbor Relation
AoA	Angle of Arrival
APAC	Asia Pacific, Africa and China
APN	Access Point Name
ARFCN	Absolute Radio Frequency Channel Number
ARP	Allocation Retention Priority
ARPU	Average Revenue Per User
ARQ	Automatic Repeat request
AS	Application Server
ATB	Adaptive Transmission Bandwidth

ATCF	Access Transfer Control Function
ATGW	Access Transfer Gateway Function
ATM	Asynchronous Transfer Mode
AWS	Advanced Wireless Services (band)
BBIC	Baseband Integrated Circuit
BCCH	Broadcast Control Channel
BCH	Broadcast Channel
BE	Best Effort
BER	Bit Error Rate
BICC	Bearer Independent Call Control
BIP	Bearer Independent Protocol
BLEP	Block Error Probability
BLER	Block Error Rate
BPSK	Binary Phase Shift Keying
BQS	Bad Quality Sample
BS	Base Station
BSC	Base Station Controller
BSR	Buffer Status Report
BSS	Business Support System
BTS	Base Transceiver Station
BW	Bandwidth
CA	Carrier Aggregation
CAMEL	Customised Applications for Mobile networks Enhanced Logic
CAPEX	Capital Expenditure
CAT	Category (user equipment)
CAZAC	Constant Amplitude Zero AutoCorrelation
CB	Coordinated Beam forming
CC	Component Carrier
CCCH	Common Control Channel
CCN	Cell Change Notification
CCO	Cell Change Order
CCO	Coverage and Capacity Optimization
CDMA	Code Division Multiple Access
CDP	Charging Downstream Port
CDR	Call Drop Rate
CDR	Charging Data Record
CDR	Clock Drift Ratio
CES	Circuit Emulated Services
CET	Carrier Ethernet Transport
C/I	Carrier per Interference
CIO	Cell Individual Offset
CLF	Contactless Frontend
CMAS	Commercial Mobile Alert System
CN	Core Network
CoMP	Coordinated Multipoint
CoS	Class of Service
CP	Cyclic Prefix

CPE	Customer Premises Equipment
CPICH	Common Pilot Channel
CQI	Channel Quality Indicator
CRC	Cyclic Redundancy Check
CRE	Cell Range Expansion
CS	Circuit Switched
CS	Coordinated Scheduling
CSFB	Circuit Switched Fall Back
CSI	Channel State Information
CT	Core Network and Terminals (TSG)
CTIA	Cellular Telecommunications and Internet Association
CVAA	Communications and Video Accessibility Act
DAB	Digital Audio Broadcasting
DCCH	Dedicated Control Channel
DCP	Dedicated Charging Port
DCR	Dropped Call Rate
DCS	Dynamic Cell Selection
DD	Digital Dividend
DDoS	Distributed DoS
DeNodeB	Donor eNodeB element
DFCA	Dynamic Frequency and Channel Allocation
DFT	Discrete Fourier Transform
DFTS-OFDM	Discrete Fourier Transform Spread-OFDM
DHR	Dual Half Rate (voice codec)
DL	Downlink
DLDC	Downlink Dual Carrier
DL-SCH	Downlink Shared Channel
DMRS	Demodulation Reference Symbol
DM-RS	Demodulation Reference Signal
DoS	Denial of Service
DPI	Deep Packet Inspection
DRS	Dedicated Reference Symbol
DRX	Discontinuous Reception
DSCP	DiffServ Code Point
DSL	Digital Subscriber Line
DSMIPv6	Dual-Stack Mobile IPv6
DTM	Dual Transfer Mode
DTMF	Dual Tone Multi-Frequency
DTX	Discontinuous Transmission
DUT	Device Under Test
DVB-H	Digital Video Broadcasting, Handheld
DVB-T	Digital Video Broadcasting, Terrestrial
DwPTS	Downlink Pilot Timeslot
eBM-SC	Evolved Broadcast/Multicast Service Center
E-CID	Enhanced Cell ID
ECM	EPS Connection Management
E-CSCF	Emergency Call State Control Function

EDGE	Enhanced Data Rates for Global Evolution
EFL	Effective Frequency Load
EGAN	Enhanced GAN
EHPLMN	Equivalent HPLMN
eHRPD	Evolved High Rate Packet Data
eICIC	Enhanced Inter-Cell Interference Coordination
EIRP	Effective Isotropic Radiating Power
eMBMS	Evolved MBMS
EMM	EPS Mobility Management
EMR	Enhanced Measurement Reporting
eNB	Evolved NodeB
EOL	End of Life (product phase)
EPC	Evolved Packet Core
ePDG	Evolved Packet Data Gateway
EPS	Evolved Packet System
ERP	Effective Radiated Power
eSE	Embedded Secure Element
E-SMLC	Enhanced Serving Mobile Location Centre
ET	Envelope Tracking
ETSI	European Telecommunications Standards Institute
ETWS	Earthquake and Tsunami Warning System
E-UTRAN	Evolved UMTS Radio Access Network
EV-DO	Evolution-Data Only
EVM	Error Vector Magnitude
FACCH	Fast Associated Control Channel
FCC	Federal Communications Commission (USA)
FCCH	Frequency Correction Channel
FDD	Frequency Division Duplex
FDPS	Frequency-Domain Packet Scheduling
FER	Frame Erasure Rate
FF	Form Factor
FFS	For Further Study
FFT	Fast Fourier Transform
FH	Frequency Hopping
FM	Fault Management
FOMA	Freedom of Mobile Multimedia Access
FR	Frame Relay
FR	Full Rate (voice codec)
FR-AMR	AMR Full Rate
GAN	Generic Access Network
GBR	Guaranteed Bit Rate
GCF	Global Certification Forum
GERAN	GSM EDGE Radio Access Network (TSG)
GGSN	GPRS Gateway Support Node
GMLC	Gateway Mobile Location Centre
GMM	GPRS Mobility Management
GMSK	Gaussian Minimum Shift Keying

GoS	Grade of Service
GP	Guard Period
GPRS	General Packet Radio Service
GRE	Generic Routing Encapsulation
GRX	GPRS Roaming Exchange
GSM	Global System for Mobile communications
GSMA	GSM Association
GTP	GPRS Tunnelling Protocol
GTT	Global Text Telephony
GTT-CS	Global Text Telephony over video telephony
GTTP	GPRS Transparent Transport Protocol
GTT-Voice	Global Text Telephony over voice
GW	Gateway
HARQ	Hybrid Automatic Retransmission on request/Hybrid Automatic Repeat Request
HD	High Definition
HDSL	High-bit-rate Digital Subscriber Line
HeNB	Home eNB
HLR	Home Location Register
HO	Handover
hPCRF	Home Policy and Charging Rules Function
HPLMN	Home PLMN
HR	Half Rate (voice codec)
HR-AMR	AMR Half Rate
HRPD	High Rate Packet Data
HSCSD	High Speed Circuit Switched Data
HSDPA	High Speed Downlink Packet Access
HSPA	High Speed Packet Access
HSS	Home Subscriber Server
HSUPA	High Speed Uplink Packet Access
ICI	Inter-Carrier Interference
ICIC	Inter Cell Interference Control
ICS	IMS Centralized Services
I-CSCF	Interrogating Call State Control Function
IDFT	Inverse Discrete Fourier Transform
IE	Information Element
IEEE	Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Task Force
IFFT	Inverse Fast Fourier Transform
I-HSPA	Internet HSPA
IMEI	International Mobile Equipment Identity
IMS	IP Multimedia Sub-system
IMSI	International Mobile Subscriber Identity
IMS-MGW	IMS-Media Gateway
IMS-NNI	IMS Network-Network Interface
IM-SSF	IP Multimedia – Service Switching Function
IMT-2000	International Mobile Telecommunication requirements (ITU)

IMT-Advanced	Advanced International Mobile Telecommunication requirements (ITU)
IN	Intelligent Network
INAP	Intelligent Network Application Protocol
IoT	Internet of Things
IOT	Inter-Operability Testing
IP	Internet Protocol
IPSec	IP Security
IP-SM-GW	IP-Short Message-Gateway
IPv4	IP version 4
IPv6	IP version 6
IPX	IP eXchange
IPXS	IP interconnection of services
IQ	In-phase (I) and out of phase (Q) components of modulation
IRC	Interference Rejection Combining
ISI	Inter-Symbol Interference
ISIM	IMS Subscriber Identity Module
ISR	Idle Mode Signalling Reduction
ISUP	ISDN User Part
ITU	International Telecommunication Union
ITU-R	ITU's Radiocommunication Sector
ITU-T	ITU's Telecommunication sector
JAIN	Java APIs for Integrated Networks
JP	Joint Processing
JSLEE	JAIN Service Logic Execution Environments
JT	Joint Transmission
KPI	Key Performance Indicator
LA	Link Adaptation
LA	Location Area
LAU	Location Area Update
LBO	Local Breakout
LBS	Location Based Service
LCS	Location Service
LI	Lawful/Legal Interception
LIG	Legal Interception Gateway
LIPA	Local IP Access
LNF	Log Normal Fading (margin)
LPP	LTE Positioning Protocol
LPPa	LPP annex
LRF	Location Retrieval Function
LSP	Label Switch Path
LTE	Long Term Evolution
LTE-A	LTE-Advanced
LTE-UE	LTE User Equipment
MA	Mobile Allocation
MAC	Medium Access Control
MAIO	Mobile Allocation Index Offset
MAN	Metropolitan Area Network

MBI	MIMO Band Index
MBMS	Multimedia Broadcast Multicast Service
MBR	Maximum Bit Rate
MBSFN	MBMS Single Frequency Network area
MCC	Mobile Country Code
MCCH	Multicast Control Channel
MCE	Multi-cell/multicast Coordination Entity
MCH	Multicast Channel
MCS	Modulation and Coding Scheme
MC-TD-SCDMA	Multi-Carrier Time-Division Synchronous-Code-Division Multiple Access
MC-WCDMA	Multi-Carrier Wide-band Code-Division Multiple Access
MDT	Minimization of Drive Tests
ME id	Mobile Equipment Identifier
MEG	Mean Effective Gain
MER	Modulation Error Rate
MGCF	Media Gateway Control Function
MGW	Media Gateway
MHA	Mast Head Amplifier
MIMO	Multiple Input Multiple Output
MM	Mobility Management
MME	Mobility Management Entity
MMS	Multimedia Messaging Service
MMTel	Multimedia Telephony
MNC	Mobile Network Code
MO	Mobile Originating (call)
MOBSS	Multi-Operator Base Station Subsystem
MOCN	Multi-Operator Core Network
MORAN	Multi-Operator Radio Access Network
MOS	Mean Opinion Score
MPLS	Multi-Protocol Label Switching
MRF	Media Resource Function
MRFC	Media Resource Function Controller
MRFP	Media Resource Function Processor
MRM	Measurement Report Message
MRO	Mobility Robustness/handover Optimization
MS	Mobile Station
MSC	Mobile services Switching Center
MSC-B	Second MSC
MSISDN	Mobile Station ISDN number
MT	Mobile Terminating (call)
MTCH	Multicast Traffic Channel
MT-LR	Mobile Terminating Location Request
MTM	Machine-to-Machine (communications); also M2M
MVNO	Mobile Virtual Network Operator
NA	Network Assisted
NACC	Network Assisted Cell Change
NACK	Negative Acknowledgment

NAS	Non Access Stratum
NAS SMC	NAS Security Mode Command
NB	Node B
NBC	Non-Backwards Compatible
NCCR	Network Controlled Cell Reselection
NDS	Network Domain Security
NE	Network Element
NE Id	Network Element Identifier
NFC	Near Field Communications
NGMN	Next Generation Mobile Networks (Alliance)
NGN	Next Generation Network
NH	Next Hop (parameter)
NITZ	Network Initiated Time Zone
NNI	Network-Network Interface
NOC	Network Operations Centre
NRT	Near Real Time
NVAS	Network Value Added Services
OAM&P	Operations, Administration, Maintenance, and Provisioning
OEM	Original Equipment Manufacturer
OFDMA	Orthogonal Frequency Division Multiple Access
OLLA	Outer Loop Link Adaptation
OLPC	Open Loop Power Control
OMS	Operations and Management System
OPEX	Operating Expenditure
OSC	Orthogonal Sub Channel
OSPIH	Internet Hosted Octect Stream Protocol
OSS	Operational Support System
OTA	Over the Air
OTDOA	Observed Time Difference of Arrival
OTT	Over the Top
P2P	Peer-to-Peer
PA	Power Amplifier
PAPR	Peak-to-Average Power Ratio
PAS	Power Azimuth Spectrum
PBCH	Physical Broadcast Channel
PBR	Prioritized Bit Rate
PBX	Private Branch Exchange
PC	Power Control
PCC	Policy and Charging Control
PCC	Primary Component Carrier
PCCH	Paging Control Channel
PCEF	Policy and Charging Enforcement Function
PCEP	Policy and Charging Enforcement Point
PCH	Paging Channel
PCI	Physical Cell Identifier
PCRF	Policy and Charging Rules Function
P-CSCF	Proxy Call State Control Function