FROM GSM TO LTE-ADVANCED PRO AND 5G

AN INTRODUCTION TO MOBILE NETWORKS AND MOBILE BROADBAND

FOURTH EDITION

MARTIN SAUTER

WILEY

Table of Contents

- Cover
- Title Page
- Copyright Page
- Preface to Fourth Edition
- 1 Global System for Mobile Communications (GSM)
  - 1.1 Circuit-Switched Data Transmission
  - 1.2 Standards
  - 1.3 Transmission Speeds
  - 1.4 The Signaling System Number 7
  - 1.5 The GSM Subsystems
  - 1.6 The Network Subsystem
  - 1.7 The Base Station Subsystem (BSS) and Voice Processing
  - 1.8 Mobility Management and Call Control
  - 1.9 The Mobile Device
  - 1.10 The SIM Card
  - 1.11 The Intelligent Network Subsystem and CAMEL
  - Questions
  - References
- 2 General Packet Radio Service (GPRS) and EDGE
  - 2.1 Circuit-Switched Data Transmission over GSM
  - 2.2 Packet-Switched Data Transmission over GPRS
  - 2.3 The GPRS Air Interface
  - 2.4 The GPRS State Model
  - 2.5 GPRS Network Elements

2.6 GPRS Radio Resource Management
2.7 GPRS Interfaces
2.8 GPRS Mobility Management and Session Management (GMM/SM)
Questions
References
3 Universal Mobile Telecommunications System (UMTS) and High-Speed Packet Access (HSPA)
3.1 Overview
3.2 Important New Concepts of UMTS
3.3 Code Division Multiple Access (CDMA)
3.4 UMTS Channel Structure on the Air Interface
3.5 The UMTS Terrestrial Radio Access Network (UTRAN)
3.6 Core Network Mobility Management
3.7 Radio Network Mobility Management
3.8 UMTS CS and PS Call Establishment
3.9 UMTS Security
3.10 High-Speed Downlink Packet Access (HSDPA) and HSPA+
3.11 High-Speed Uplink Packet Access (HSUPA)
3.12 Radio and Core Network Enhancements: CPC
3.13 Radio Resource State Management
3.14 Automated Emergency Calls (eCall) from Vehicles
Questions
References
4 Long Term Evolution (LTE) and LTE-Advanced Pro
4.1 Introduction and Overview

4.2 Network Architecture and Interfaces
4.3 FDD Air Interface and Radio Network
4.4 TD-LTE Air Interface
4.5 Scheduling
4.6 Basic Procedures
4.7 Mobility Management and Power Optimization
4.8 LTE Security Architecture
4.9 Interconnection with UMTS and GSM
4.10 Carrier Aggregation
4.11 Network Planning Aspects
4.12 CS-Fallback for Voice and SMS Services with LTE
4.13 Network Sharing – MOCN and MORAN
4.14 From Dipoles to Active Antennas and Gigabit Backhaul
4.15 IPv6 in Mobile Networks
4.16 Network Function Virtualization
4.17 Machine Type Communication and the Internet of Things
Questions
References
5 VoLTE, VoWifi, and Mission Critical Communication
5.1 Overview
5.2 The Session Initiation Protocol (SIP)
5.3 The IP Multimedia Subsystem (IMS) and VoLTE
5.4 VoLTE Roaming
5.5 Voice over WiFi (VoWifi)
5.6 VoLTE Compared to Fixed-Line IMS in Practice
5.7 Mission Critical Communication (MCC)

Questions
References
6 5G New Radio (NR) and the 5G Core
6.1 Introduction and Overview
6.2 5G NR Non-Standalone (NSA) Architecture
6.3 5G TDD Air Interface
6.4 5G FDD Air Interface
6.5 EN-DC Bearers and Scheduling
6.6 Basic Procedures and Mobility Management in Non-Standalone Mode
6.7 Network Planning and Deployment Aspects
6.8 5G NR Standalone (SA) Architecture and Basic Procedures
6.9 The 5G Air Interface in Standalone Operation
6.10 Future 5G Functionalities
Questions
References
7 Wireless Local Area Network (WLAN)
7.1 Wireless LAN Overview
7.2 Transmission Speeds and Standards
7.3 WLAN Configurations: From Ad Hoc to Wireless Bridging
7.4 Management Operations
7.5 The MAC Layer
7.6 The Physical Layer and MAC Extensions
7.7 Wireless LAN Security
7.8 IEEE 802.11e and WMM – Quality of Service
Questions
References

8 Bluetooth and Bluetooth Low Energy
8.1 Overview and Applications
8.2 Physical Properties
8.3 Piconets and the Master/Slave Concept
8.4 The Bluetooth Protocol Stack
8.5 Bluetooth Security
8.6 Bluetooth Profiles
8.7 Bluetooth Low Energy
Questions
References
Index
End User License Agreement

List of Tables

Chapter 1

Table 1.1 STM transmission speeds and number of DS0s.
Table 1.2 Mobile country codes.
Table 1.3 Basic services of a GSM network.
Table 1.4 Supplementary services of a GSM network.
Table 1.5 GSM frequency bands.
Table 1.6 GSM power levels and corresponding power output.
Table 1.7 SIM card properties.
Table 1.8 Examples for APDU commands.

Table 1.9 Some fields of the response APDU for a SELECT command.

Chapter 2

Table 2.1 Selected GPRS multislot classes from 3GPP (3rd Generation Partnersh...

Table 2.2 GPRS coding schemes.

Table 2.3 EDGE modulation and coding schemes (MCS).

Table 2.4 Re-segmentation of EDGE blocks using a different MCS.

Chapter 3

Table 3.1 Spreading factors and datarates.

Table 3.2 Spreading and scrambling in uplink and downlink directions.

Table 3.3 AMR codecs and bit rates.

Table 3.4 RNC and SGSN states.

Table 3.5 Core network and radio network states.

Table 3.6 A selection of HSDPA mobile device categories.

Table 3.7 Spreading code sets and maximum resulting speed of different E-DCH ...

Chapter 4

Table 4.1 LTE UE categories.

Table 4.2 Typical LTE frequency bands that are simultaneously supported by hi...

Table 4.3 Defined bandwidths for LTE.

Table 4.4 System information blocks and content overview.

Table 4.5 LTE transmission modes.

Table 4.6 Downlink control channel message types (DCI formats).

Table 4.7 UE categories and the number of supported carriers for carrier aggr...

Table 4.8 CA bandwidth classes.

Chapter 6

Table 6.1 Frequency bands for 5G TDD deployments in FR1.

Table 6.2 Examples of typical 3.5 GHz (n78) spectrum assignments as of 2020.

Table 6.3 Modulation schemes used on the NR air interface.

Table 6.4 Maximum data rate of a single user LTE/5G split downlink bearer.

Table 6.5 FR2 bands.

Table 6.6 Frequency bands used or likely to be used in the near future with t...

Chapter 7

Table 7.1 Different PHY standards.

Table 7.2 Additional 802.11 standard documents that describe optional functio...

Table 7.3 802.11g datarates.

Table 7.4 Comparison of PHY carrier parameters of 802.11g vs. 11n.

Table 7.5 Feature combinations and resulting transmission speeds.

Table 7.6 Modulation and coding schemes in 802.11ac.

Table 7.7 Achievable 802.11ac datarates in practice.

Table 7.8 Important new features of 802.11ax.

Table 7.9 Radio layer parameter comparison between 802.11ac, 802.11ax, and LT...

Table 7.10 60 GHz channel availability in different regions.

Chapter 8

Table 8.1 Bluetooth versions.

Table 8.2 ACL packet types.

Table 8.3 SCO packet types.

Table 8.4 ACL packet types.

Table 8.5 Selection of HCI commands.

Table 8.6 Bluetooth profiles for different applications.

List of Illustrations

Chapter 1

Figure 1.1 Switching matrix in a switching center.

Figure 1.2 Necessary software changed to adapt a fixed-line switching center...

Figure 1.3 Timeslot architecture of an E-1 connection.

Figure 1.4 An SS-7 network with an STP, two SCP databases, and three switchi...

Figure 1.5 Comparison of the SS-7, OSI, and TCP/IP protocol stacks.

Figure 1.6 Establishment of a voice call between two switching centers.

Figure 1.7 Enhancement of the SS-7 protocol stack for GSM.

Figure 1.8 Comparison of the classic and IP-based SS-7 protocol stacks.

Figure 1.9 Interfaces and nodes in a classic NSS architecture.

Figure 1.10 Interfaces and nodes in an IP-based NSS architecture.

Figure 1.11 Digitization of an analog voice signal.

Figure 1.12 Mobile Switching Center (MSC) with integrated Visitor Location R...

Figure 1.13 The International Mobile Subscriber Identity (IMSI).

Figure 1.14 Creation of a signed response (SRES).

Figure 1.15 Message flow during the authentication of a subscriber.

Figure 1.16 Authentication between network and mobile device.

Figure 1.17 SMS delivery principle.

Figure 1.18 GSM uplink and downlink in the 900 MHz frequency band.

Figure 1.19 A typical antenna of a GSM base station. The optional microwave ...

Figure 1.20 Cellular structure of a GSM network.

Figure 1.21 Sectorized cell configurations.

Figure 1.22 A GSM TDMA frame.

Figure 1.23 A GSM burst.

Figure 1.24 Arrangement of bursts of a frame for the visualization of logica...

Figure 1.25 Use of timeslots in the downlink direction per 3GPP TS 45.002 [2...

Figure 1.26 Time shift of bursts of distant subscribers without timing advan...

Figure 1.27 Establishment of a signaling connection.

Figure 1.28 Mapping of E-1 timeslots to air interface timeslots.

Figure 1.29 Establishment of a traffic channel (TCH).

Figure 1.30 Message flow during a handover procedure.

Figure 1.31 GSM speech compression.

Figure 1.32 Speech compression with a 4:1 compression ratio in the TRAU.

Figure 1.33 Source–filter model of the GSM FR codec.

Figure 1.34 Complete transmission chain with the transmitter and receiver of...

Figure 1.35 Transmission path in the downlink direction between the network ...

Figure 1.36 GSM channel coder for full-rate speech frames.

Figure 1.37 Frame interleaving.

Figure 1.38 Ciphering of an air interface burst.

Figure 1.39 Message flow for a location update procedure.

Figure 1.40 Discontinuous transmission (DTX).

Figure 1.41 Cells in different location areas.

Figure 1.42 Mobile-terminated call establishment, part 1.

Figure 1.43 Mobile-terminated call establishment, part 2.

Figure 1.44 Inter-MSC handover.

Figure 1.45 Subsequent inter-MSC handover.

Figure 1.46 Architecture of a smartphone.

Figure 1.47 Example of a tool to visualize the data contained on a SIM card....

Figure 1.48 Block diagram of SIM card components.

Figure 1.49 Structure of a command APDU.

Figure 1.50 Response APDU.

Figure 1.51 Structure of the SELECT command APDU.

Figure 1.52 Simplified state model for an originator (O-BCSM) according to 3...

Chapter 2

Figure 2.1 Exclusive connections of a circuit-switched system.

Figure 2.2 Packet-switched data transmission.

Figure 2.3 Billing based on volume.

Figure 2.4 Simplified visualization of PDTCH assignment and timeslot aggrega...

Figure 2.5 Shared use of the timeslots of a cell for GSM and GPRS.

Figure 2.6 CS-2 and CS-3 channel coder.

Figure 2.7 GMSK (GPRS) and 8-PSK (EDGE) modulation.

Figure 2.8 MCS-9 convolutional coding and incremental redundancy.

Figure 2.9 Paging for an incoming voice call via the Gs interface.

Figure 2.10 PDTCH and PACCH are sent on the same timeslot.

Figure 2.11 GPRS logical channels.

Figure 2.12 Packet resources: requests and assignments.

Figure 2.13 The GPRS state model.

Figure 2.14 Difference between ready and standby states.

Figure 2.15 GPRS network nodes.

Figure 2.16 Interfaces and protocols of the SGSN on layers 2 and 3.

Figure 2.17 Ciphering in GSM and GPRS.

Figure 2.18 Subscriber changes location within the GPRS network.

Figure 2.19 Use of the uplink state flag (USF).

Figure 2.20 Use of the temporary flow identifier (TFI) in the downlink direc...

Figure 2.21 Packet Timeslot Reconfiguration message according to 3GPP TS 44....

Figure 2.22 GPRS protocol stacks in the radio network.

Figure 2.23 The Gn interface protocol stack.

Figure 2.24 GTP packet on the Gn interface.

Figure 2.25 The Gr interface.

Figure 2.26 The Gp interface.

Figure 2.27 GPRS attach message flow.

Figure 2.28 GPRS Attach message on the Gb interface.

Figure 2.29 The PDP context activation procedure.

Figure 2.30 Identification of user data packets on different GPRS interfaces...

Chapter 3

Figure 3.1 Common GSM/UMTS network: Release 99.

Figure 3.2 UMTS Release 4 (Bearer-Independent Core Network).

Figure 3.3 Separation of protocols between the core and radio network into A...

Figure 3.4 Simultaneous communication of several users with a base station i...

Figure 3.5 Simultaneous conversation between two users with a single base st...

Figure 3.6 Relation between spreading factor, chip rate, processing gain, an...

Figure 3.7 The OVSF code tree.

Figure 3.8 Spreading and scrambling.

Figure 3.9 Cell breathing.

Figure 3.10 User and control planes.

Figure 3.11 Logical, transport, and physical channels in downlink direction ...

Figure 3.12 Logical, transport, and physical channels in uplink direction (w...

Figure 3.13 Network search after the mobile device is switched on.

Figure 3.14 Initial network access procedure (RRC connection setup) as descr...

Figure 3.15 Preparation of user data frames for air interface (Uu) transmiss...

Figure 3.16 User data transmission in downlink direction via the complex I-p...

Figure 3.17 User data transmission via the I-path only.

Figure 3.18 RNC protocols and interfaces for user data (user plane).

Figure 3.19 RNC protocols and interfaces used for signaling (control plane)....

Figure 3.20 Factors influencing the Quality of Service and the maximum bandw...

Figure 3.21 Radio Resource Control (RRC) states.

Figure 3.22 Discontinuous Transmission (DTX) on a dedicated channel reduces ...

Figure 3.23 Data of different subscribers is time multiplexed on the FACH.

Figure 3.24 UMTS hard handover.

Figure 3.25 Connections to a mobile device during a soft handover procedure ...

Figure 3.26 Soft handover reduces the energy consumption of the mobile due t...

Figure 3.27 Use of scrambling codes while a mobile device is in soft handove...

Figure 3.28 Soft handover with S-RNC and D-RNC.

Figure 3.29 SRNS relocation procedure.

Figure 3.30 3G to 2G handover.

Figure 3.31 A UMTS cell with several GSM neighboring cells presents a proble...

Figure 3.32 3G–2G intersystem hard handover message flow.

Figure 3.33 Cell change in PMM connected state to a cell that cannot communi...

Figure 3.34 Location concepts of radio and core network.

Figure 3.35 Messaging for a mobile-originated voice call (MOC).

Figure 3.36 Radio resource allocation for a voice traffic channel.

Figure 3.37 PDP context activation.

Figure 3.38 Simplified HSDPA channel overview in downlink direction.

Figure 3.39 Simplified HSDPA channel overview in uplink direction.

Figure 3.40 Detection and report of a missing frame with immediate retransmi...

Figure 3.41 Establishment of an HSDPA connection.

Figure 3.42 Transport and Physical Channels used for HSUPA.

Figure 3.43 Simultaneous downlink channels for simultaneous HSUPA, HSDPA, an...

Figure 3.44 E-DCH protocol stack.

Figure 3.45 Serving E-DCH cell, serving RLS, and non-serving RLS.

Figure 3.46 Control channel switch-off during times with little activity.

Figure 3.47 Message exchange to move a mobile device from URA-PCH state back...

Chapter 4

Figure 4.1 LTE network overview.

Figure 4.2 S1 control plane (a) and user plane (b) protocol stacks.

Figure 4.3 Physical routing of the S1 and the X2 interface.

Figure 4.4 LTE international roaming with home routing.

Figure 4.5 Principles of OFDMA for downlink transmission.

Figure 4.6 Principles of SC-FDMA for uplink transmission.

Figure 4.7 16-QAM modulation.

Figure 4.8 LTE resource grid.

Figure 4.9 Symbols in a resource block used for the reference signal.

Figure 4.10 LTE downlink channel structure.

Figure 4.11 LTE channel uplink structure.

Figure 4.12 Random access procedure.

Figure 4.13 Simplified illustration of MIMO operation.

Figure 4.14 Synchronous HARQ in the downlink direction.

Figure 4.15 Air interface protocol stack and main functions.

Figure 4.16 Downlink data reception overview.

Figure 4.17 PSS and SSS in an LTE FDD frame.

Figure 4.18 Attach and default bearer activation message flow – part 1.

Figure 4.19 Attach and default bearer activation message flow – part 2.

Figure 4.20 X2-based handover message flow.

Figure 4.21 Basic S1-based handover.

Figure 4.22 Short and long DRX cycles.

Figure 4.23 Interconnection of LTE to GSM and UMTS networks.

Figure 4.24 CA configuration during RRC connection establishment.

Figure 4.25 Use of PCell and SCell resources, DRX and Idle to save power.

Figure 4.26 Fractional frequency reuse for reducing cell-edge interference….

Figure 4.27 SGs interconnection for delivery of SMS messages.

Figure 4.28 IPv6 default bearer establishment.

Figure 4.29 An IPv6 Router Advertisement sent during tethering.

Figure 4.30 An Ubuntu Linux host running Windows as a guest operating system...

Figure 4.31 The NB-IoT channel resource grid.

Figure 4.32 CIoT Control Plane Optimization and Non-IP Data Delivery.

Chapter 5

Figure 5.1 The basic SIP infrastructure.

Figure 5.2 SIP Register message.

Figure 5.3 SIP call establishment.

Figure 5.4 List of codecs in the SDP section of a SIP Invite message.

Figure 5.5 The basic IMS components.

Figure 5.6 The IMS registration procedure.

Figure 5.7 VoLTE call establishment part 1.

Figure 5.8 VoLTE call establishment part 2.

Figure 5.9 AMR-WB codec in an RTP packet.

Figure 5.10 An RTP frame with an embedded DTMF signaling message. The messag...

Figure 5.11 An SMS message being sent over SIP.

Figure 5.12 IMS and MSC components required for SRVCC.

Figure 5.13 A speech connection before and after an SRVCC handover.

Figure 5.14 VoLTE Local Breakout.

Figure 5.15 VoLTE S8HR.

Figure 5.16 VoWifi network architecture and the ePDG.

Figure 5.17 ePDG VPN session establishment.

Figure 5.18 Fixed-line IMS call establishment.

Figure 5.19 MCPTT application server in IMS.

Figure 5.20 Signaling for establishment of a ‘Pre-Arranged Group Call.’

Figure 5.21 MCPTT and eMBMS network nodes.

Chapter 6

Figure 6.1 5G New Radio Non-Standalone Architecture.

Figure 6.2 Base Station Site components.

Figure 6.3 5G New Radio deployment options.

Figure 6.4 Typical NR air interface configuration in band n78.

Figure 6.5 Synchronization and broadcast information configuration example....

Figure 6.6 Traditional LTE 2 × 2 MIMO antenna vs 5G Active Antenna System (A...

Figure 6.7 A rooftop cell site installation with classic 2 × 2 MIMO antennas...

Figure 6.8 Typical NR air interface configuration on band n78.

Figure 6.9 5G NR air interface downlink channels.

Figure 6.10 5G NR uplink channels.

Figure 6.11 Dynamic Spectrum Sharing (DSS) between LTE and NR.

Figure 6.12 An LTE Frame with MBSFN subframes.

Figure 6.13 Use of 2 UE transmitters for EN-DC with a split downlink and LTE...

Figure 6.14 LTE anchor setup for a 5G EN-DC bearer – part 1.

Figure 6.15 LTE anchor setup for a 5G EN-DC bearer – part 2.

Figure 6.16 LTE/NR split bearer setup.

Figure 6.17 Split-bearer configuration in downlink and LTE-only bearer in up...

Figure 6.18 Different steps of an EN-DC handover procedure.

Figure 6.19 The basic components of the 5G Core Network (5GC).

Figure 6.20 UE registration message flow.

Figure 6.21 GTP tunneling with a 5G core network.

Figure 6.22 Session Establishment.

Figure 6.23 5G Handover with an Xn interface between two gNBs.

Figure 6.24 LTE and NR core network interconnection for inter-RAT mobility....

Figure 6.25 Context transfer procedure when moving from 4G to 5G in RRC-Idle...

Chapter 7

Figure 7.1 The WLAN protocol stack.

Figure 7.2 Infrastructure BSS.

Figure 7.3 Access point, IP router, and DSL modem in a single device.

Figure 7.4 ESS with three access points.

Figure 7.5 Overlapping coverage of access points forming an ESS.

Figure 7.6 Client device configuration for a BSS or ESS.

Figure 7.7 An extract from a beacon frame.

Figure 7.8 Authentication and association of a client device with an access ...

Figure 7.9 Reassociation (acknowledgment frames not shown).

Figure 7.10 Activation and deactivation of PS mode (acknowledgment frames no...

Figure 7.11 Acknowledgment for every frame and required interframe space per...

Figure 7.12 Reservation of the air interface via RTS/CTS frames.

Figure 7.13 MAC and LLC header of a WLAN frame.

Figure 7.14 Complementary code keying for 11 Mbit/s transmissions.

Figure 7.15 Simplified representation of OFDM subchannels.

Figure 7.16 Default frame transmission compared to frame aggregation.

Figure 7.17 2 × 2 MIMO.

Figure 7.18 PLCP header variants.

Figure 7.19 A Power Save Multipoll (PSMP) window in which several clients tr...

Figure 7.20 PHY packet structure.

Figure 7.21 WPA-PSK authentication and ciphering key exchange.

Figure 7.22 EAP-TLS authentication.

Figure 7.23 EAP-TTLS certificate authentication.

Figure 7.24 EAP-SIM authentication.

Figure 7.25 Protocols used in the EAP-SIM authentication process.

Figure 7.26 A Beacon frame indicating PMF support.

Figure 7.27 Comparison of authentication with and without PMF support.

Figure 7.28 Disassociation with and without PMF support.

Figure 7.29 WMM priority classes with example values for CWmin, CWmax, and T...

Figure 7.30 QoS field in an IP packet.

Figure 7.31 Packet bursting and block acknowledgments.

Chapter 8

Figure 8.1 Three examples of achievable Bluetooth datarates depending on the...

Figure 8.2 By using different hopping sequences, many piconets can coexist i...

Figure 8.3 Data exchange between a master and three slave devices.

Figure 8.4 The Bluetooth protocol stack.

Figure 8.5 Composition of an ACL packet.

Figure 8.6 The ACL payload field including the ACL header and checksum.

Figure 8.7 Retransmission of an eSCO packet caused by a transmission error....

Figure 8.8 Establishment of a connection between two Bluetooth devices.

Figure 8.9 Communication between two link managers via the LMP.

Figure 8.10 Establishment of a connection via the HCI command.

Figure 8.11 Multiplexing of several data streams.

Figure 8.12 Establishment of a connection to a service.

Figure 8.13 Multiplexing on different protocol layers.

Figure 8.14 The different steps of a Bluetooth connection establishment.

Figure 8.15 Pairing procedure between two Bluetooth devices.

Figure 8.16 Authentication of a Bluetooth remote device.

Figure 8.17 Bluetooth encryption using a ciphering sequence.

Figure 8.18 Protocol stack for the SPP.

Figure 8.19 Protocol stack of the OBEX file transfer profile.

Figure 8.20 XML-encoded directory structure.

Figure 8.21 The FTP, object push, and synchronization profiles are based on ...

Figure 8.22 The headset profile protocol stack.

Figure 8.23 Establishment of the signaling and the speech channels.

Figure 8.24 Structure of the SIM access profile.

Figure 8.25 The protocol stack used for A2DP and remote control.

Figure 8.26 Simultaneous audio streaming and control connections to differen...

Figure 8.27 HID input message sent from a keyboard.

Figure 8.28 Bluetooth Low Energy protocol stack.

Figure 8.29 A BLE 4.0/4.1 link layer packet.

Figure 8.30 BLE Connect Request packet excerpt.

Figure 8.31 A GATT Read Request.

Figure 8.32 A GATT Read Response.

Figure 8.33 A practical example.

Figure 8.34 IPv6 over Bluetooth Low Energy.

From GSM to LTE-Advanced Pro and 5G

An Introduction to Mobile Networks and Mobile Broadband

Fourth Edition

Martin Sauter
WirelessMoves
Cologne
Germany

WILEY

This fourth edition first published 2021
© 2021 John Wiley & Sons Ltd

Edition History
John Wiley and Sons Ltd (1e 2011); John Wiley and Sons Ltd (2e 2014); John Wiley and Sons Ltd (3e 2017)

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording or otherwise, except as permitted by law. Advice on how to obtain permission to reuse material from this title is available at http://www.wiley.com/go/permissions.

The right of Martin Sauter to be identified as the author of this work has been asserted in accordance with law.

Registered Offices
John Wiley & Sons, Inc., 111 River Street, Hoboken, NJ 07030, USA
John Wiley & Sons Ltd, The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, UK

Editorial Office
The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, UK

For details of our global editorial offices, customer services, and more information about Wiley products visit us at www.wiley.com.

Wiley also publishes its books in a variety of electronic formats and by print-on-demand. Some content that appears in standard print versions of this book may not be available in other formats.

Limit of Liability/Disclaimer of Warranty
While the publisher and authors have used their best efforts in preparing this work, they make no representations or warranties with respect to the accuracy or completeness of the contents of this work and specifically disclaim all warranties, including without limitation any implied warranties of merchantability or fitness for a particular purpose. No warranty may be created or extended by sales representatives, written sales materials or promotional statements for this work. The fact that an organization, website, or product is referred to in this work as a citation and/or potential source of further information does not mean that the publisher and authors endorse the information or services the organization, website, or product may provide or recommendations it may make. This work is sold with the understanding that the publisher is not engaged in rendering professional services. The advice and strategies contained herein may not be suitable for your situation. You should consult with a specialist where appropriate. Further, readers should be aware that websites listed in this work may have changed or disappeared between when this work was written and when it is read. Neither the publisher nor authors shall be liable for any loss of profit or any other commercial damages, including but not limited to special, incidental, consequential, or other damages.

Library of Congress Cataloging-in-Publication Data

Names: Sauter, Martin, author. | John Wiley & Sons, Ltd., publisher.
Title: From GSM to LTE-Advanced Pro and 5G : an introduction to mobile networks and mobile broadband / Martin Sauter.
Other titles: From GSM to LTE
Description: Fourth edition. | Hoboken, NJ : Wiley, 2021. | Includes bibliographical references and index.
Identifiers: LCCN 2020031695 (print) | LCCN 2020031696 (ebook) | ISBN 9781119714675 (cloth) | ISBN 9781119714705 (adobe pdf) | ISBN 9781119714699 (epub)
Subjects: LCSH: Mobile communication systems. | Global system for mobile communications. | Long-Term Evolution (Telecommunications). | 5G mobile communication systems.
Classification: LCC TK5103.2 .S28 2021 (print) | LCC TK5103.2 (ebook) | DDC 621.3845/6–dc23
LC record available at https://lccn.loc.gov/2020031695
LC ebook record available at https://lccn.loc.gov/2020031696

Cover Design: Wiley
Cover Images: Abstract background with purple and brown polygons © Hamster3d/Getty Images, binary code © ABIDAL/Getty Images, Illuminated Fernsehturm And Cityscape Against Sky At Night © Philip Gaube/EyeEm/Getty Images

Preface to Fourth Edition

Wireless technologies like GSM, UMTS, LTE, VoLTE, 5G NR, Wireless LAN, and Bluetooth have revolutionized the way we communicate by making services like telephony and Internet access available anytime and from almost anywhere. Currently, a great variety of technical publications offer background information about these technologies but they all fall short in one way or another. Books covering these technologies usually describe only one of the systems in detail and are generally too complex as a first introduction. The Internet is also a good source, but the articles one finds are usually too short and superficial or only deal with a specific mechanism of one of the systems. For this reason, it was difficult for me to recommend a single publication to students in my telecommunication classes, which I have been teaching in addition to my work in the wireless telecommunication industry. This book aims to change this.

Each of the eight chapters in this book gives a detailed introduction to and overview of one of the wireless systems mentioned above, and how it has been deployed in practice. Special emphasis has also been put on explaining the thoughts and reasoning behind the development of each system. For readers who want to test their understanding of a system, each chapter concludes with a list of questions. For further investigation, all chapters contain references to the relevant standards and documents. These provide ideal additional sources to find out more about a specific system or topic. In addition, a companion website with further background information and the latest news is available at http://www.wirelessmoves.com.