

## 5g New Air Interface And Radio Access Virtualization

This book provides a comprehensive overview of the latest research and standardization progress towards the 5th generation (5G) of mobile communications technology and beyond. It covers a wide range of topics from 5G use cases and their requirements, to spectrum, 5G end-to-end (E2E) system architecture including core network (CN), transport network (TN) and radio access network (RAN) architecture, network slicing, security and network management. It further dives into the detailed functional design and the evaluation of different 5G concepts, and provides details on planned trials and pre-commercial deployments across the globe. While the book naturally captures the latest agreements in 3rd Generation Partnership Project (3GPP) New Radio (NR) Release 15, it goes significantly beyond this by describing the likely developments towards the final 5G system that will ultimately utilize a wide range of spectrum bands, address all envisioned 5G use cases, and meet or exceed the International Mobile Telecommunications (IMT) requirements for the year 2020 and beyond (IMT-2020).

*5G System Design: Architectural and Functional Considerations and Long Term Research* is based on the knowledge and consensus from 158 leading researchers and standardization experts from 54 companies or institutes around the globe, representing key mobile network operators, network vendors, academic institutions and regional bodies for 5G. Different from earlier books on 5G, it does not focus on single 5G technology components, but describes the full 5G system design from E2E architecture to detailed functional design, including details on 5G performance, implementation and roll-out. Mobile communication technologies are growing rapidly in order to serve the world with better

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spectral efficiency, higher data rates and lower latency. Each decade, a slew of electronic devices are released that require access to wireless networks, leading the need in designing efficient air interface. Evolution of 5G Technology will demand higher data rates than 4G-LTE systems. It is a challenge for scientists and researchers, working on wireless networks, to come together and find the best air interface which can support tremendous data rates while combating power losses and cost of bandwidth. Orthogonal Frequency Division Multiplexing (OFDM) is a well-known air interface, chosen as the best choice for 4G-LTE and its evolution so far. 4G-LTE was invented by 3rd generation partnership program (3GPP) group. OFDM has also been used for IEEE 802.11(Wi-Fi). In this thesis, we study the sensitivity of OFDM to Peak to Average power ratio and then proceed to compare this aspect with other proposed air interface alternatives for 5G, i.e. Universal filtered OFDM (UF-OFDM) also known as Universal filtered multicarrier (UFMC). We perform link level simulations for UFMC in comparison with OFDM. The comparisons are done on physical layer, and Peak to Average power ratio values in both downlink and uplink scenarios are considered for link level simulations. To our best knowledge, this is the first project done so far in order to analyze and reduce PAPR value on UFMC. We notice that UFMC gives higher PAPR values than OFDM. Even though UFMC has encouraging results so far to be the contender for 5G, this waveform design still carries the disadvantage from previous generation in terms of PAPR. We need to mitigate the effect of higher PAPR in order to make UFMC feasible for 5G. We study through our simulation that this PAPR values can be different while varying some of the filter parameters being used by UFMC. Also, we can combat higher PAPR values by applying PAPR reduction methods, like signal distortion method or signal scrambling methods. In addition to this, we study a system

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architecture when we occupy some frequency bands for 4G and leave the rest for 5G in order to support transmission during early deployment of 5G and evaluate its PAPR values. The simulations are performed in Matlab R2012b running on a Windows 7 (x64) machine. Written in a clear and concise manner, this book presents readers with an in-depth discussion of the 5G technologies that will help move society beyond its current capabilities. It perfectly illustrates how the technology itself will benefit both individual consumers and industry as the world heads towards a more connected state of being. Every technological application presented is modeled in a schematic diagram and is considered in depth through mathematical analysis and performance assessment. Furthermore, published simulation data and measurements are checked. Each chapter of 5G Physical Layer Technologies contains texts, mathematical analysis, and applications supported by figures, graphs, data tables, appendices, and a list of up to date references, along with an executive summary of the key issues. Topics covered include: the evolution of wireless communications; full duplex communications and full dimension MIMO technologies; network virtualization and wireless energy harvesting; Internet of Things and smart cities; and millimeter wave massive MIMO technology. Additional chapters look at millimeter wave propagation losses caused by atmospheric gases, rain, snow, building materials and vegetation; wireless channel modeling and array mutual coupling; massive array configurations and 3D channel modeling; massive MIMO channel estimation schemes and channel reciprocity; 3D beamforming technologies; and linear precoding strategies for multiuser massive MIMO systems. Other features include: In depth coverage of a hot topic soon to become the backbone of IoT connecting devices, machines, and vehicles Addresses the need for green communications for the 21st century Provides a comprehensive support for

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the advanced mathematics exploited in the book by including appendices and worked examples Contributions from the EU research programmes, the International telecommunications companies, and the International standards institutions (ITU; 3GPP; ETSI) are covered in depth Includes numerous tables and illustrations to aid the reader Fills the gap in the current literature where technologies are not explained in depth or omitted altogether 5G Physical Layer Technologies is an essential resource for undergraduate and postgraduate courses on wireless communications and technology. It is also an excellent source of information for design engineers, research and development engineers, the private-public research community, university research academics, undergraduate and postgraduate students, technical managers, service providers, and all professionals involved in the communications and technology industry.

An important outcome of the Fourth World Internet Conference, this book provides a comprehensive account of the status quo and trends in global Internet development. Covering network infrastructure, information technology, digital economy, e-governance, cyber security, and international cyberspace governance, it presents the Global Internet Development Index System to assess the Internet development of various major countries and emerging economies.

This book presents a detailed pedagogical description of the 5G commercial wireless communication system design, from an end to end perspective. It compares and contrasts NR with LTE, and gives a concise and highly accessible description of the key technologies in the 5G physical layer, radio access network layer protocols and procedures. This book also illustrates how the 5G core and EPC is integrated into the radio access network, how

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virtualization and edge computer fundamentally change the way users interact with the network, as well as 5G spectrum issues. This book is structured into six chapters. The first chapter reviews the use cases, requirements, and standardization organization and activities for 5G. These are 5G requirements and not NR specifically, as technology that meets the requirements, may be submitted to the ITU as 5G technology. This includes a set of Radio Access Technologies (RATs), consisting of NR and LTE; with each RAT meeting different aspects of the requirements. The second chapter describes the air interface of NR and LTE side by side. The basic aspects of LTE that NR builds upon are first described, followed by sections on the NR specific technologies, such as carrier/channel, spectrum/duplexing (including SUL), LTE/NR co-existence and new physical layer technologies (including waveform, Polar/LDPC codes, MIMO, and URLLC/mMTC). In all cases the enhancements made relative to LTE are made apparent. The third chapter contains descriptions of NR procedures (IAM/Beam Management/Power control/HARQ), protocols (CP/UP/mobility, including grant-free), and RAN architecture. The fourth chapter includes a detailed discussion related to end-to-end system architecture, and the 5G Core (5GC), network slicing, service continuity, relation to EPC, network virtualization, and edge computing. The fifth and major chapter describes the ITU submission and how NR and LTE meet the 5G requirements in significant detail, from the rapporteur responsible for leading the preparation and evaluation, as well as some field trial results. Engineers, computer scientists and professionals with a passing knowledge of 4G LTE and a comprehensive understanding of the end to end 5G commercial wireless system will find this book to be a valuable asset. Advanced-level students and researchers studying and working in communication engineering, who want to gain an

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understanding of the 5G system (as well as methodologies to evaluate features and technologies intended to supplement 5G) will also find this book to be a valuable resource. As technology advances, the emergence of 5G has become an essential discussion moving forward as its applications and benefits are expected to enhance many areas of life. The introduction of 5G technology to society will improve communication speed, the efficiency of information transfer, and end-user experience to name only a few of many future improvements. These new opportunities offered by 5G networks will spread across industry, government, business, and personal user experiences leading to widespread innovation and technological advancement. What stands at the very core of 5G becoming an integral part of society is the very fact that it is expected to enrich society in a multifaceted way, enhancing connectivity and efficiency in just about every sector including healthcare, agriculture, business, and more. Therefore, it has been a critical topic of research to explore the implications of this technology, how it functions, what industries it will impact, and the challenges and solutions of its implementation into modern society. Research Anthology on Developing and Optimizing 5G Networks and the Impact on Society is a critical reference source that analyzes the use of 5G technology from the standpoint of its design and technological development to its applications in a multitude of industries. This overall view of the aspects of 5G networks creates a comprehensive book for all stages of the implementation of 5G, from early conception to application in various sectors. Topics highlighted include smart cities, wireless and mobile networks, radio access technology, internet of things, and more. This all-encompassing book is ideal for network experts, IT specialists, technologists, academicians, researchers, and students.

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A comprehensive overview of the 5G landscape covering technology options, most likely use cases and potential system architectures.

Examine the challenges of 4G in the light of impending and crucial future communication needs, and review the lessons learned from an implementation and system operation perspective with an eye towards the next generation – 5G. You'll investigate key changes and additions to 5G in terms of use cases. You'll also learn about the applications for and explorations of the technology. Among all of the technological disruptions, two stand out in particular – mmWave and spectrum sharing technologies. Rolling Out 5G features detailed coverage of these two critical topics, and for the first time among 5G learning resources presents a holistic perspective on key ingredients for mobile communication in a 5G world. The authors represent highly experienced experts with valuable know-how in the field of wireless communications related research projects defining future technological trends. This unique group of talents will be able to consider the 5G technology evolution from all angles mentioned: long-term research, standardization and regulation, product design and marketization. This approach allows this much-needed book to capture the views of all key decision making stakeholders involved in the 5G definition process, and to serve readers in their roles connected with wireless communication's next generation of products and services. What You'll Learn See how 5G is expected to overcome 4G insufficiencies and challenges Examine expected 5G features, including usage of millimeter wave communication and licensed shared access Review key milestones of the next generation wireless communication technology including key standardization and regulation bodies Study new technologies and upcoming changes in feature sets and client expectations. Who This Book Is For Engineers of mobile device and

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infrastructure manufacturing industries, development engineers of semiconductor manufacturing industries, and engineers with a general interest in the field. Mobile network operators, along with students and business professionals in the telecommunications domain will also find the topic of interest.

Updated new edition covering all aspects of network planning and optimization  
This welcome new edition provides comprehensive coverage of all aspects of network planning in all the technologies, from 2G to 5G, in radio, transmission and core aspects. Written by leading experts in the field, it serves as a handbook for anyone engaged in the study, design, deployment and business of cellular networks. It increases basic understanding of the currently deployed, and emerging, technologies, and helps to make evolution plans for future networks. The book also provides an overview of the forthcoming technologies that are expected to make an impact in the future, such as 5G. Fundamentals of Cellular Network Planning and Optimization, Second Edition encompasses all the technologies as well as the planning and implementation details that go with them. It covers 2G (GSM, EGPRS), 3G (WCDMA) and 4G (LTE) networks and introduces 5G. The book also looks at all the sub-systems of the network, focusing on both the practical and theoretical issues. Provides comprehensive coverage of the planning aspects of the full range of today's mobile network

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systems, covering radio access network, circuit and packet switching, signaling, control, and backhaul/Core transmission networks New elements in book include HSPA, Ethernet, 4G/LTE and 5G Covers areas such as Virtualization, IoT, Artificial Intelligence, Spectrum Management and Cloud By bringing all these concepts under one cover, Fundamentals of Cellular Network Planning and Optimization becomes essential reading for network design engineers working with cellular service vendors or operators, experts/scientists working on end-to-end issues, and undergraduate/post-graduate students.

Fundamentals of 5G NR Networks : Architecture, Concepts and Applicability in 5G is an in-depth, systematic and structured technical reference on 3GPP's New Radio standards (Release 15 and beyond), covering underlying theory, technology and implementation of the new 5G radio interface. The book describes the operation of individual components and shows how they fit into the overall system and operate from a systems perspective. Uniquely, this book gives detailed information on upper RAN protocol layers, network architecture and services, implementation and deployment issues, and applications, making it suitable for engineers who are developing 5G products and services. Reflecting on the author's 30-plus years of experience in signal processing and wireless communication system design, this book is ideal for professional engineers,

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researchers and graduate students working and researching in cellular communication systems, radio air-interface technologies, cellular communications protocols, advanced radio access technologies for 5G systems, and broadband cellular standards.

Learn how radio access network (RAN) slicing allows 5G networks to adapt to a wide range of environments in this masterful resource *Radio Access Network Slicing and Virtualization for 5G Vertical Industries* provides readers with a comprehensive and authoritative examination of crucial topics in the field of radio access network (RAN) slicing. Learn from renowned experts as they detail how this technology supports and applies to various industrial sectors, including manufacturing, entertainment, public safety, public transport, healthcare, financial services, automotive, and energy utilities. *Radio Access Network Slicing and Virtualization for 5G Vertical Industries* explains how future wireless communication systems must be built to handle high degrees of heterogeneity, including different types of applications, device classes, physical environments, mobility levels, and carrier frequencies. The authors describe how RAN slicing can be utilized to adapt 5G technologies to such wide-ranging circumstances. The book covers a wide range of topics necessary to understand RAN slicing, including: Physical waveforms design Multiple service signals coexistence RAN

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slicing and virtualization Applications to 5G vertical industries in a variety of environments This book is perfect for telecom engineers and industry actors who wish to identify realistic and cost-effective concepts to support specific 5G verticals. It also belongs on the bookshelves of researchers, professors, doctoral, and postgraduate students who want to identify open issues and conduct further research.

Fifth-generation cellular radio access networks are currently being standardized as 5G New Radio (NR). The primary objectives of 5G NR are to provide enhanced mobile broadband (eMBB) and ultra-reliable low latency communication (URLLC) capabilities. This innovative resource analyzes these applications in detail to help readers understand how the flexible design of NR makes it suitable for a wide range of use cases and applications. The rationale behind the design decisions made during the NR standardization process are explored. Readers will be able to understand the performance limits of NR when applied to non-eMBB scenarios and how NR compares to 4G and IEEE 802.x connectivity solutions for such scenarios. The main features of 5G phase 2 are explored, as well as the use cases that can be addressed by 5G phase 2. The mathematical models are included to help explain the future evolution of NR in Release 16 and beyond. This is the only book that describes both the standards

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features of NR and the mathematical models/open research issues for 5G, appealing to both industry practitioners and academic researchers.

A comprehensive text to an understanding the next generation mobile broadband and wireless Internet of Things (IoT) technologies 5G Verticals brings together in one comprehensive volume a group of visionaries and technical experts from academia and industry. The expert authors discuss the applications and technologies that comprise 5G verticals. The earlier network generations (2G to 4G) were designed as on-size-fits-all, general-purpose connectivity platforms with limited differentiation capabilities. 5G networks have the capability to demand customizable mobile networks and create an ecosystem for technical and business innovation involving vertical markets such as automotive, healthcare, manufacturing, energy, food and agriculture, city management, government, public transportation, media and more. 5G will serve a large portfolio of applications with various requirements ranging from high reliability to ultra-low latency going through high bandwidth and mobility. In this book, the authors explore applications and usages of various 5G verticals including a set of key metrics for these uses and their corresponding target requirements. The book also examines the potential network architectures and enabling technologies to meet the requirements of 5G verticals. This important book: Offers a

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comprehensive resource to the promise of 5G Verticals Provides a set of key metrics for the uses and target requirements Contains illustrative examples of the technology and applications Includes contributions from experts in the field and professionals that developed the 5G standards Provides an analysis of specific vertical industries which have the potential to be among the first industries to use 5G Written for industry practitioners, engineers and researchers, 5G Verticals discusses the technology that enables the 5G system to be flexibly deployed and scaled.

NG-RAN and 5G-NR describes the deployment of 5G NSA (non standalone 5G) and 5G-SA (standalone 5G). 5G-NSA deals with radio access entities. For the 5G-NSA mode, dual MR DC connectivity is based on radio measurements, allowing the master 4G base station MeNB to add or remove a secondary 5G node SgNB. This book describes the architecture of the NG radio access network and the 5G-NR radio interface according to the 3GPP (3rd Generation Partnership Project) specifications. The overall architecture of the NG-RAN, including the NG, Xn and F1 interfaces and their interaction with the radio interface, are also described. The 5G-NR physical layer is mainly connected by implementing antennas, which improves transmission capacity. 5G-SA deals with the 5G Core network. In the 5G-SA model, the mobile is attached to the 5G Core

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network through NG-RAN. The book explains radio procedure, from switching on a device to establishing a data connection, and how this connection is maintained even if mobility is involved for both 5G-SA and 5G-NSA deployment. NG-RAN and 5G-NR is devoted to the radio access network, but mobile registration, establishment procedures and re-establishment procedures are also explained. This book takes China Mobile's "5G +" plan as the mainline, introduces three major scenarios, nine indicators, system architecture and basic principles of 5G, and systematically explains the essence of China Mobile's "5G +" for the first time. A lot of industry use cases and solutions are introduced for 5G to bring new changes to life, industries, and social governance. This book can benefit all readers who are interested in 5G. It also can be a reference for vertical industry partners to fully understand the possible applications of 5G. Most of all, it will help to promote all industries with new developments based on 5G's new kinetic energy.

This book presents comprehensive coverage of current and emerging multiple access, random access, and waveform design techniques for 5G wireless networks and beyond. A definitive reference for researchers in these fields, the book describes recent research from academia, industry, and standardization bodies. The book is an all-encompassing treatment of these areas addressing

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orthogonal multiple access and waveform design, non-orthogonal multiple access (NOMA) via power, code, and other domains, and orthogonal, non-orthogonal, and grant-free random access. The book builds its foundations on state of the art research papers, measurements, and experimental results from a variety of sources.

Provides a thorough introduction to the development, operation, maintenance, and troubleshooting of mobile communications systems *Mobile Communications Systems Development: A Practical Approach for System Understanding, Implementation and Deployment* is a comprehensive “how to” manual for mobile communications system design, deployment, and support. Providing a detailed overview of end-to-end system development, the book encompasses operation, maintenance, and troubleshooting of currently available mobile communication technologies and systems. Readers are introduced to different network architectures, standardization, protocols, and functions including 2G, 3G, 4G, and 5G networks, and the 3GPP standard. In-depth chapters cover the entire protocol stack from the Physical (PHY) to the Application layer, discuss theoretical and practical considerations, and describe software implementation based on the 3GPP standardized technical specifications. The book includes figures, tables, and sample computer code to help readers thoroughly comprehend the functions and underlying concepts of a mobile communications network. Each chapter includes an introduction to the topic and a chapter summary. A full list of references, and a set of exercises are also provided at the end of the book to test comprehension and strengthen understanding of the material. Written by a respected professional with more than

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20 years' experience in the field, this highly practical guide: Provides detailed introductory information on GSM, GPRS, UMTS, and LTE mobile communications systems and networks  
Describes the various aspects and areas of the LTE system air interface and its protocol layers  
Covers troubleshooting and resolution of mobile communications systems and networks issues  
Discusses the software and hardware platforms used for the development of mobile communications systems network elements Includes 5G use cases, enablers, and architectures that cover the 5G NR (New Radio) and 5G Core Network Mobile Communications Systems Development is perfect for graduate and postdoctoral students studying mobile communications and telecom design, electronic engineering undergraduate students in their final year, research and development engineers, and network operation and maintenance personnel.

Over the past few decades, wireless access networks have evolved extensively to support the tremendous growth of consumer traffic. This superlative growth of data consumption has come about due to several reasons, such as evolution of the consumer devices, the types of telephone and smartphone being used, convergence of services, digitisation of economic transactions, tele-education, telemedicine, m-commerce, virtual reality office, social media, e-governance, e-security, to name but a few. Not only has the society transformed to a digital world, but also the expectations from the services provided have increased many folds. The last mile/meters of delivery of all e-services is now required to be wireless. It has always been known that wireless links are the bottleneck to providing high data rates and high quality of service. Several wireless signalling and performance analysis techniques to overcome the hurdles of wireless channels have been developed over the last decade, and these are fuelling

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the evolution of 4G towards 5G. Evolution of Air Interface Towards 5G attempts to bring out some of the important developments that are contributing towards such growth.

An expert treatment of the state-of-the-art in green and soft communications, covering theory, design, and resource management strategies.

Practical Guide Provides Students and Industry Professionals with Latest Information on 5G Mobile Networks Continuing the tradition established in his previous publications, Jyrki Penttinen offers 5G Explained as a thorough yet concise introduction to recent advancements and growing trends in mobile telecommunications. In this case, Penttinen focuses on the development and employment of 5G mobile networks and, more specifically, the challenges inherent in adjusting to new global standardization requirements and in maintaining a high level of security even as mobile technology expands to new horizons. The text discusses, for example, the Internet of Things (IoT) and how to keep networks reliable and secure when they are constantly accessed by many different devices with varying levels of user involvement and competence. 5G Explained is primarily designed for specialists who need rapid acclimation to the possibilities and concerns presented by 5G adoption. Therefore, it assumes some prior knowledge of mobile communications. However, earlier chapters are structured so that even relative newcomers will gain useful information. Other notable features include: Three modules each consisting of three chapters: Introduction, Technical Network Description and Planning of Security and Deployment Comprehensive coverage of topics such as technical requirements for 5G, network architecture, radio and core networks and services/applications Discussion of specific security techniques in addition to common-sense guidelines for planning, deploying, managing and optimizing 5G networks 5G Explained offers crucial updates for anyone involved

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in designing, deploying or working with 5G networks. It should prove a valuable guide for operators, equipment manufacturers and other professionals in mobile equipment engineering and security, network planning and optimization, and mobile application development, or anyone looking to break into these fields.

A revised edition of the text that offers a comparative introduction to global wireless standards, technologies, and their applications The revised and updated fourth edition of From GSM to LTE-Advanced Pro and 5G: An Introduction to Mobile Networks and Mobile Broadband offers an authoritative guide to the technical descriptions of the various wireless technologies currently in use. The author—a noted expert on the topic—explains the rationale behind their differing mechanisms and implementations while exploring the advantages and limitations of each technology. The fourth edition reflects the significant changes in mobile network technology that have taken place since the third edition was published. The text offers a new chapter on 5G NR that explores its non-standalone and standalone architecture. In the Wi-Fi chapter, additional sections focus on the new WPA3 authentication protocol, the new 802.11ax air interface and protocol extensions like 802.11k and 11v for meshed networks. This important book: Presents the various systems based on the standards, their practical implementation and design assumptions, and their performance and capacity Provides an in-depth analysis of each system in practice Offers an updated edition of the most current changes to mobile network technology Includes questions at the end of each chapter and answers on the accompanying website that make this book ideal for self-study or as course material Written for students and professionals of wireless technologies, the revised fourth edition of From GSM to LTE-Advanced Pro and 5G provides an in-depth review and description of the most current mobile

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networks and broadband.

A comprehensive guide to 5G technology, applications and potential for the future 5G brings new technology solutions to the 5G mobile networks including new spectrum options, new antenna structures, new physical layer and protocols designs and new network architectures. 5G Technology: 3GPP New Radio is a comprehensive resource that offers explanations of 5G specifications, performance evaluations, aspects of device design, practical deployment considerations and illustrative examples from field experiences. With contributions from a panel of international experts on the topic, the book presents the main new technology components in 5G and describes the physical layer, radio protocols and network performance. The authors review the deployment aspects such as site density and transport network and explore the 5G performance aspects including data rates and coverage and latency. The book also contains illustrative examples of practical field measurement. In addition, the book includes the most recent developments in 4G LTE evolution and offers an outlook for the future of the evolution of 5G. This important book: Offers an introduction to 5G technology and its applications Contains contributions from international experts on the topic Reviews the main technology components in 5G Includes information on the optimisation of the Internet of things Presents illustrative examples of practical field measurements Written for students and scientists interested in 5G technology, 5G Technology: 3GPP New Radio provides a clear understanding of the underlying 5G technology that promotes the opportunity to take full benefit of new capabilities.

A comprehensive and invaluable guide to 5G technology, implementation and practice in one single volume. For all things 5G, this book is a must-read. Signal processing techniques have

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played the most important role in wireless communications since the second generation of cellular systems. It is anticipated that new techniques employed in 5G wireless networks will not only improve peak service rates significantly, but also enhance capacity, coverage, reliability, low-latency, efficiency, flexibility, compatibility and convergence to meet the increasing demands imposed by applications such as big data, cloud service, machine-to-machine (M2M) and mission-critical communications. This book is a comprehensive and detailed guide to all signal processing techniques employed in 5G wireless networks. Uniquely organized into four categories, New Modulation and Coding, New Spatial Processing, New Spectrum Opportunities and New System-level Enabling Technologies, it covers everything from network architecture, physical-layer (down-link and up-link), protocols and air interface, to cell acquisition, scheduling and rate adaption, access procedures and relaying to spectrum allocations. All technology aspects and major roadmaps of global 5G standard development and deployments are included in the book. Key Features: Offers step-by-step guidance on bringing 5G technology into practice, by applying algorithms and design methodology to real-time circuit implementation, taking into account rapidly growing applications that have multi-standards and multi-systems. Addresses spatial signal processing for 5G, in particular massive multiple-input multiple-output (massive-MIMO), FD-MIMO and 3D-MIMO along with orbital angular momentum multiplexing, 3D beamforming and diversity. Provides detailed algorithms and implementations, and compares all multicarrier modulation and multiple access schemes that offer superior data transmission performance including FBMC, GFDM, F-OFDM, UPMC, SEFDM, FTN, MUSA, SCMA and NOMA. Demonstrates the translation of signal processing theories into practical solutions for new spectrum opportunities in terms of millimeter wave, full-

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duplex transmission and license assisted access. Presents well-designed implementation examples, from individual function block to system level for effective and accurate learning. Covers signal processing aspects of emerging system and network architectures, including ultra-dense networks (UDN), software-defined networks (SDN), device-to-device (D2D) communications and cloud radio access network (C-RAN).

A comprehensive and approachable introduction to 5G Written by a noted expert on the subject, *An Introduction to 5G: The New Radio, 5G Network and Beyond* offers an introductory system-level guide to 5G. The material covered includes: The use cases and requirements of the 5G system The architecture of the next generation radio access network and the 5G core The principles of radio transmission, millimetre waves and MIMO antennas The architecture and detailed design of the 5G new radio The implementation of HTTP/2 on the service-based interfaces of the 5G core The signalling procedures that govern the end-to-end-operation of the system The new features that are introduced in Releases 16 and 17 *An Introduction to 5G* is written for engineering professionals in mobile telecommunications, for those in non-technical roles such as management, marketing and intellectual property, and for students. It requires no more than a basic understanding of mobile communications, and includes detailed references to the underlying 3GPP specifications for 5G. The book's approach provides a comprehensive, end-to-end overview of the 5G standard, which enables readers to move on with confidence to the more specialized texts and to the specifications themselves.

This book constitutes the refereed post-conference proceedings of the 23rd International Conference on Distributed and Computer and Communication Networks, DCCN 2020, held in Moscow, Russia, in September 2020. The 54 revised full papers and 1 revised short paper

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were carefully reviewed and selected from 167 submissions. The papers cover the following topics: computer and communication networks; analytical modeling of distributed systems; and distributed systems applications.

This book brings together a group of visionaries and technical experts from academia to industry to discuss the applications and technologies that will comprise the next set of cellular advancements (5G). In particular, the authors explore usages for future 5G communications, key metrics for these usages with their target requirements, and network architectures and enabling technologies to meet 5G requirements. The objective is to provide a comprehensive guide on the emerging trends in mobile applications, and the challenges of supporting such applications with 4G technologies.

5G New RadioA Beam-based Air InterfaceJohn Wiley & Sons

Discover how the NG-RAN architecture is, and isn't, ready for the challenges introduced by 5G

5G Radio Access Network Architecture: The Dark Side of 5G explores foundational and advanced topics in Radio Access Network (RAN) architecture and why a re-thinking of that architecture is necessary to support new 5G requirements. The distinguished engineer and editor Sasha Sirotkin has included numerous works written by industry insiders with state of the art research at their disposal. The book explains the relevant standards and technologies from an academic perspective, but also explains why particular standards decisions were made and how a variety of NG-RAN architecture options could be deployed in real-life networks. All major standards and technologies associated with the NG-RAN architecture are discussed in this book, including 3GPP, O-RAN, Small Cell Forum, IEEE, and IETF. Readers will learn about how a re-design of the RAN architecture would ensure that 5G networks can

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deliver their promised throughput and low latency KPIs consistently and sustainably. The book is structured as follows: An overview of the market drivers of the NG-RAN architecture, like spectrum models, 5G-relevant regulatory considerations, and 5G radio interface technical requirements An overview of the 5G System, from the core network, to the RAN, to the radio interface protocols and physical layer, with emphasis on how these are different compared to 4G Release-15 RAN architectures defined in 3GPP, O-RAN, and Small Cell Forum RAN architecture evolution in Release-16 and Release-17 Enabling technologies, like virtualization, open source technologies, multi-access edge (MEC) computing, and operations, administration, and management (OAM) NG-RAN deployment considerations, objectives, and challenges, like costs, spectrum and radio propagation considerations, and coverage Perfect for network designers and operators who require a solid understanding of the NG-RAN architecture, 5G Radio Access Network Architecture also belongs on the bookshelves of network engineers who aim to increase their understanding of the standards and technologies relevant to the NG-RAN architecture.

5G Outlook - Innovations and Applications is a collection of the recent research and development in the area of the Fifth Generation Mobile Technology (5G), the future of wireless communications. Plenty of novel ideas and knowledge of the 5G are presented in this book as well as divers applications from health science to business modeling. The authors of different chapters contributed from various countries and organizations. The chapters have also been presented at the 5th IEEE 5G Summit held in Aalborg on July 1, 2016. The book starts with a comprehensive introduction on 5G and its need and requirement. Then millimeter waves as a promising spectrum to 5G technology is discussed. The book continues with the novel and

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inspiring ideas for the future wireless communication usage and network. Further, some technical issues in signal processing and network design for 5G are presented. Finally, the book ends up with different applications of 5G in distinct areas. Topics widely covered in this book are: 5G technology from past to present to the future Millimeter- waves and their characteristics Signal processing and network design issues for 5G Applications, business modeling and several novel ideas for the future of 5G

This book constitutes the proceedings of the First International Conference on Future Access Enablers for Ubiquitous and Intelligent Infrastructures, FABULOUS 2015, held in Ohrid, Republic of Macedonia, in September 2015. The 39 revised papers cover the broad areas of future wireless networks, ambient and assisted living, smart infrastructures and security and reflect the fast developing and vibrant penetration of IoT technologies in diverse areas of human live.

This is the Black and White version of '5G New Radio in Bullets', printed as a paperback with 590 pages and dimensions of 21.6 x 27.9 cm. This book provides a comprehensive description of the 5G New Radio (NR) radio access network. The content is aimed towards anyone wishing to learn the basics, or to develop a more thorough understanding. The content is presented in the form of bullet points to keep it concise and to allow rapid access to the key information. The text includes both introductory and advanced topics and is supported by more than 480 illustrations and 350 tables. The book is based upon the release 15 version of the specifications. Practical Radio Network Planning topics are discussed after presenting the theoretical background. The content is organised as: Fundamentals; Air Interface; Downlink Signals and Channels; Downlink Transmission Schemes; Flow of Downlink Data; System

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Information; Uplink Signals and Channels; Uplink Transmission Schemes; Beam Management; UE Measurements; Idle Mode Procedures; Physical and MAC Layer Procedures; Voice Services; Signalling Procedures; Radio Network Planning; Dynamic Spectrum Sharing. A reliable and focused treatment of the emergent technology of fifth generation (5G) networks. This book provides an understanding of the most recent developments in 5G, from both theoretical and industrial perspectives. It identifies and discusses technical challenges and recent results related to improving capacity and spectral efficiency on the radio interface side, and operations management on the core network side. It covers both existing network technologies and those currently in development in three major areas of 5G: spectrum extension, spatial spectrum utilization, and core network and network topology management. It explores new spectrum opportunities; the capability of radio access technology; and the operation of network infrastructure and heterogeneous QoE provisioning. 5G Networks: Fundamental Requirements, Enabling Technologies, and Operations Management is split into five sections: Physical Layer for 5G Radio Interface Technologies; Radio Access Technology for 5G Networks; 5G Network Interworking and Core Network Advancements; Vertical 5G Applications; and R&D and 5G Standardization. It starts by introducing emerging technologies in 5G software, hardware, and management aspects before moving on to cover waveform design for 5G and beyond; code design for multi-user MIMO; network slicing for 5G networks; machine type communication in the 5G era; provisioning unlicensed LAA interface for smart grid applications; moving toward all-IT 5G end-to-end infrastructure; and more. This valuable resource: Provides a comprehensive reference for all layers of 5G networks Focuses on fundamental issues in an easy language that is understandable by a wide audience Includes

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both beginner and advanced examples at the end of each section Features sections on major open research challenges 5G Networks: Fundamental Requirements, Enabling Technologies, and Operations Management is an excellent book for graduate students, academic researchers, and industry professionals, involved in 5G technology.

"This book addresses the advantages and the limitations of modern multicarrier technologies and how to meet the challenges they pose using non-contiguous multicarrier technologies and novel algorithms that enhance spectral efficiency, interference robustness, and reception performance. It explores techniques using non-contiguous subcarriers which allow for flexible spectrum aggregation while achieving high spectral efficiency and flexible transmission and reception at lower OSI layers. These include non-contiguous orthogonal frequency division multiplexing (NC-OFDM), its enhanced version, non-contiguous filter-bank-based multicarrier (NC-FBMC), and generalized multicarrier. Following an overview of current multicarrier technologies for radio communication, the authors examine particular properties of these technologies that allow for more efficient usage within key directions of 5G. They examine the principles of NC-OFDM and discuss efficient transmitter and receiver design. They present the principles of FBMC modulation and discuss key challenges for FBMC communications while comparing performance results with traditional OFDM. They move on from there

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to a fascinating discussion of GMC modulation within which they clearly demonstrate how that technology encompasses all of the advantages of previously discussed techniques, as well as all imaginable multi- and single-carrier waveforms. [...]" (source : 4ème de couverture.

An Introduction to 5G Wireless Networks book is for students, engineers, managers and for marketing/sales executives, to develop a good understanding of the 5G technology. This book covers the 5G architecture, 5G New Radio (NR), 5G Next Generation Core (NG-Core), Network Slicing, Virtualization of 5G Components, Multi-access Edge Computing (MEC) and the various 5G use cases. This book provides details on the evolution of the wireless networks from 1G to 5G, status of 5G deployments and the 5G marketplace (standard bodies, open source communities and vendors). After reading this book, you will be able to have discussions with customers, interviewers and other stakeholders on the 5G concepts, ecosystem and use-cases.

Comprehensive Handbook Demystifies 5G for Technical and Business Professionals in Mobile Telecommunication Fields Much is being said regarding the possibilities and capabilities of the emerging 5G technology, as the evolution towards 5G promises to transform entire industries and many aspects of our society. 5G for the Connected World offers a comprehensive technical overview

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that telecommunication professionals need to understand and take advantage of these developments. The book offers a wide-ranging coverage of the technical aspects of 5G (with special consideration of the 3GPP Release 15 content), how it enables new services and how it differs from LTE. This includes information on potential use cases, aspects of radio and core networks, spectrum considerations and the services primarily driving 5G development and deployment. The text also looks at 5G in relation to the Internet of Things, machine to machine communication and technical enablers such as LTE-M, NB-IoT and EC-GSM. Additional chapters discuss new business models for telecommunication service providers and vertical industries as a result of introducing 5G and strategies for staying ahead of the curve. Other topics include: Key features of the new 5G radio such as descriptions of new waveforms, massive MIMO and beamforming technologies as well as spectrum considerations for 5G radio regarding all possible bands Drivers, motivations and overview of the new 5G system – especially RAN architecture and technology enablers (e.g. service-based architecture, compute-storage split and network exposure) for native cloud deployments Mobile edge computing, Non-3GPP access, Fixed-Mobile Convergence Detailed overview of mobility management, session management and Quality of Service frameworks 5G security vision and architecture Ultra-low

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latency and high reliability use cases and enablers, challenges and requirements (e.g. remote control, industrial automation, public safety and V2X communication) An outline of the requirements and challenges imposed by massive numbers of devices connected to cellular networks While some familiarity with the basics of 3GPP networks is helpful, 5G for the Connected World is intended for a variety of readers. It will prove a useful guide for telecommunication professionals, standardization experts, network operators, application developers and business analysts (or students working in these fields) as well as infrastructure and device vendors looking to develop and integrate 5G into their products, and to deploy 5G radio and core networks.

This book constitutes the joint refereed proceedings of the 18th International Conference on Next Generation Wired/Wireless Advanced Networks and Systems, NEW2AN 2018, the 11th Conference on Internet of Things and Smart Spaces, ruSMART 2018. The 64 revised full papers presented were carefully reviewed and selected from 186 submissions. The papers of NEW2AN focus on advanced wireless networking and applications; lower-layer communication enablers; novel and innovative approaches to performance and efficiency analysis of ad-hoc and machine-type systems; employed game-theoretical formulations, Markov chain models, and advanced queuing theory; grapheme

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and other emerging material, photonics and optics; generation and processing of signals; and business aspects. The ruSMART papers deal with fully-customized applications and services.

How 5G technology can support the demands of multiple vertical industries  
Recent advances in technology have created new vertical industries that are highly dependent on the availability and reliability of data between multiple locations. The 5G system, unlike previous generations, will be entirely data driven—addressing latency, resilience, connection density, coverage area, and other vertical industry criteria. Enabling 5G Communication Systems to Support Vertical Industries demonstrates how 5G communication systems can meet the needs unique to vertical industries for efficient, cost-effective delivery of service. Covering both theory and practice, this book explores solutions to problems in specific industrial sectors including smart transportation, smart agriculture, smart grid, environmental monitoring, and disaster management. The 5G communication system will have to provide customized solutions to accommodate each vertical industry's specific requirements. Whether an industry practitioner designing the next generation of wireless communications or a researcher needing to identify open issues and classify their research, this timely book: Covers the much-discussed topics of supporting multiple vertical

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industries and new ICT challenges Addresses emerging issues and real-world problems surrounding 5G technology in wireless communication and networking Explores a comprehensive array of essential topics such as connected health, smart transport, smart manufacturing, and more Presents important topics in a clear, concise style suitable for new learners and professionals alike Includes contributions from experts and industry leaders, system diagrams, charts, tables, and examples Enabling 5G Communication Systems to Support Vertical Industries is a valuable resource telecom engineers industry professionals, researchers, professors, doctorate, and postgraduate students requiring up-to-date information on supporting vertical industries with 5G technology systems. Summarizes and surveys current LTE technical specifications and implementation options for engineers and newly qualified support staff Concentrating on three mobile communication technologies, GSM, 3G-WCDMA, and LTE—while majorly focusing on Radio Access Network (RAN) technology—this book describes principles of mobile radio technologies that are used in mobile phones and service providers' infrastructure supporting their operation. It introduces some basic concepts of mobile network engineering used in design and rollout of the mobile network. It then follows up with principles, design constraints, and more advanced insights into radio interface protocol stack,

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operation, and dimensioning for three major mobile network technologies: Global System Mobile (GSM) and third (3G) and fourth generation (4G) mobile technologies. The concluding sections of the book are concerned with further developments toward next generation of mobile network (5G). Those include some of the major features of 5G such as a New Radio, NG-RAN distributed architecture, and network slicing. The last section describes some key concepts that may bring significant enhancements in future technology and services experienced by customers. Introduction to Mobile Network Engineering: GSM, 3G-WCDMA, LTE and the Road to 5G covers the types of Mobile Network by Multiple Access Scheme; the cellular system; radio propagation; mobile radio channel; radio network planning; EGPRS - GPRS/EDGE; Third Generation Network (3G), UMTS; High Speed Packet data access (HSPA); 4G-Long Term Evolution (LTE) system; LTE-A; and Release 15 for 5G. Focuses on Radio Access Network technologies which empower communications in current and emerging mobile network systems Presents a mix of introductory and advanced reading, with a generalist view on current mobile network technologies Written at a level that enables readers to understand principles of radio network deployment and operation Based on the author's post-graduate lecture course on Wireless Engineering Fully illustrated with tables, figures, photographs, working examples

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with problems and solutions, and section summaries highlighting the key features of each technology described. Written as a modified and expanded set of lectures on wireless engineering taught by the author, *Introduction to Mobile Network Engineering: GSM, 3G-WCDMA, LTE and the Road to 5G* is an ideal text for post-graduate and graduate students studying wireless engineering, and industry professionals requiring an introduction or refresher to existing technologies. Mobile wireless communication systems have affected every aspect of life. By providing seamless connectivity, these systems enable almost all the smart devices in the world to communicate with high speed throughput and extremely low latency. The next generation of cellular mobile communications, 5G, aims to support the tremendous growth of interconnected things/devices (i.e., internet of things [IoT]) using the current technologies and extending them to be used in higher frequencies to cope with the huge number of different devices. In addition, 5G will provide massive capacity, high throughput, lower end-to-end delay, green communication, cost reduction, and extended coverage area. *Fundamental and Supportive Technologies for 5G Mobile Networks* provides detailed research on technologies used in 5G, their benefits, practical designs, and recent challenges and focuses on future applications that could exploit 5G network benefits. The content within this publication examines cellular communication, data

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transmission, and high-speed communication. It is designed for network analysts, IT specialists, industry professionals, software engineers, researchers, academicians, students, and scientists.

A guide to the 3GPP-specified 5G physical layer with a focus on the new beam-based dimension in the radio system 5G New Radio: A Beam-based Air Interface is an authoritative guide to the newly 3GPP-specified 5G physical layer. The contributors—noted experts on the topic and creators of the actual standard—focus on the beam-based operation which is a new dimension in the radio system due to the millimeter wave deployments of 5G. The book contains information that complements the 3GPP specification and helps to connect the dots regarding key features. The book assumes a basic knowledge of multi-antenna technologies and covers the physical layer aspects related to beam operation, such as initial access, details of reference signal design, beam management, and DL and UL data channel transmission. The contributors also provide a brief overview of standardization efforts, IMT-2020 submission, 5G spectrum, and performance analysis of 5G components. This important text: Contains information on the 3GPP-specified 5G physical layer Highlights the beam-based operation Covers the physical layer aspects related to beam operation Includes contributions from experts who created the standard Written for students and development

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engineers working with 5G NR, 5G New Radio: A Beam-based Air Interface offers an expert analysis of the 3GPP-specified 5G physical layer.

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